S9086-SY-STM-010/CH-551R2

REVISION 2

NAVAL SHIPS’ TECHNICAL MANUAL

CHAPTER 551

COMPRESSED AIR PLANTS AND SYSTEMS

THIS CHAPTER SUPERSEDES CHAPTER 551 DATED 1 NOVEMBER 1987

PUBLISHED BY DIRECTION OF COMMANDER, NAVAL SEA SYSTEMS COMMAND

12 NOV 1997

NAVSEA TECHNICAL MANUAL CERTIFICATION SHEET 1 of 1

Certification Applies to: New Manual ☐ Revision ☒ Change ☐

Applicable TMINS/Pub. No. S9086–SY–STM–010/CH–551R2

Publication Date (Mo, Da, Yr) November 12, 1997

Title: NSTM Chapter 551, Compressed Air Plants and Systems

TMCR/TMSR/Specification No:

CHANGES AND REVISIONS:

Purpose: Side bars in the outside margins indicate changes since the last revision. Incorporate changes and appendices provided by the Life Cycle Manager.

Equipment Alteration Numbers Incorporated:

TMDER/ACN Numbers Incorporated:

Continue on reverse side or add pages as needed.

CERTIFICATION STATEMENT

This is to certify that responsible NAVSEA activities have reviewed the above identified document for acquisition compliance, technical coverage, and printing quality. This form is for internal NAVSEA management use only, and does not imply contractual approval or acceptance of the technical manual by the Government, nor relieve the contractor of any responsibility for delivering the technical manual in accordance with the contract requirement.

Authority	Name	Signature	Organization	Code	Date
Acquisition	L. Keith Dowgewicz	J. Keith Dowgewicz	NAVSEA	03L33	11/12/97
Technical	L. Keith Dowgewicz	J. Keith Dowgewicz	NAVSEA	03L33	11/12/97
Printing Release	Digital Media Publishing				

TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

Chapter/Paragraph Page

TABLE OF CONTENTS - Continued

TABLE OF CONTENTS - Continued

Chapter/Paragraph Page

TABLE OF CONTENTS - Continued

TABLE OF CONTENTS - Continued

TABLE OF CONTENTS - Continued

Chapter/Paragraph Page

TABLE OF CONTENTS - Continued

TABLE OF CONTENTS - Continued

TABLE OF CONTENTS - Continued

Chapter/Paragraph | Page

TABLE OF CONTENTS - Continued

Chapter/Paragraph Page

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS - Continued

LIST OF ILLUSTRATIONS - Continued

LIST OF ILLUSTRATIONS - Continued

CHAPTER 551

COMPRESSED AIR PLANTS AND SYSTEMS

SECTION 1.

GENERAL

551-1.1 INTRODUCTION

551-1.1.1 This section provides information, instructions, and guidance to all personnel for the satisfactory and safe operation, inspection, and overall management of all compressed air plant components, equipment, and systems installed on ships of the U.S. Navy.

551-1.2 DEFINITION OF TERMS

551-1.2.1 The following list provides definitions of various systems and system components relative to compressed air plants and systems.

a. Absolute Pressure. The sum of gauge pressure plus atmospheric pressure.

b. Absolute Temperature. In degrees Rankine (English System of Units) equals the reading of the thermometer in degrees Fahrenheit plus 460 degrees. In degrees Kelvin (Metric System of Units) equals the reading of the thermometer in degrees Centigrade (Celsius) plus 273 degrees.

c. Adiabatic Compression. The theoretical compression process in which there is no transfer of sensible heat to or from the gas during compression. This type of compression would take place in a perfectly insulated cylinder.

d. Adsorption. Dry air by bringing it into contact with a solid desiccant.

e. Aftercoolers. Devices for removing the heat of compression from the air after the last stage of compression.

f. Air Bank. An installation of one or more air flasks to provide a reservoir of compressed air for a specific service.

g. Air Dehydrator. A device which removes water vapor, particulate matter, and oil aerosol from compressed air by cooling or adsorption to provide a clean and dry air supply.

h. Air Flask. A pressure vessel to store compressed air above 600 lb/in^2 gauge.

i. Air Receiver. A pressure vessel for the storage of air at 600 lb/in^2 gauge and below.

j. Back Pressure Regulating Valve. The function of this valve is to prevent the flow of air downstream until the upstream pressure has reached a minimum preset pressure. When installed on air compressors, it provides quicker sealing of high-pressure seals as well as maximizing the amount of water vapor condensed and separated by compressor coolers. When installed on air dehydrators, it maximizes condensation in moisture separator, and prefilters and increases adsorption of vapor by the desiccant.

k. Ballast Blow and Ventilation Compressors. Rotary compressors employing two straight or spiral lobed rotors for compression to a pressure of about 22 lb/in^2 gauge and having a relatively high capacity range between 1,100 and 2,200 scfm. A principle use of this compressor is in the Low-Pressure (LP) Main Ballast Tank (MBT) surface deballasting blow system on submarines and deballasting on amphibious ships.

l. Bleed Air System. A system which is supplied by way of bleed-connections from the compressor section of a propulsion or generator gas turbine and provides service for various functions such as anti-icing, PRAIRIE/MASKER (P/M), and subsequent gas turbine starting.

m. Centrifugal Compressors (Dynamic Type). Continuous flow machines in which rotating bladed wheels (called impellers) impart a high velocity to the air; the velocity energy developed raises the static pressure of the air without use of valves, as it is passed through a diffuser.

n. Compressed Air Plants. An arrangement of air compressors, dehydrators, receivers (or flasks) and associated piping, instrumentation, and controls for supplying compressed air demands.

o. Compressors. Machines designed for compressing air or gas from an initial intake pressure to a higher discharge pressure.

p. High-Pressure (HP) Air System. A system which is designed for a nominal operating pressure above 1,000 lb/in^2 gauge.

q. Impulse Flask. A pressure vessel for storing compressed air used for torpedo ejection.

r. Intercoolers. Devices for removing the heat of compression from the air or gas between consecutive stages of multistage compressors.

s. Isothermal Compression. The theoretical compression process in which the gas remains at a constant temperature.

t. Load Factor. The ratio of the average compressor output during a certain period of time to the maximum rated output of the machine.

u. LP Air System. A system which is designed for a nominal operating pressure of 150 lb/in^2 gauge and below.

v. Medium-Pressure (MP) Air System. A system which is designed for a nominal operating pressure of 151 lb/in^2 gauge to 1,000 lb/in^2 gauge.

w. Moisture Separator. A pressure vessel designed to remove entrained liquid contaminants from compressed air passing through it.

x. Nonvital Services. Services other than vital, such as for pneumatic tools and sea chest blowing.

y. Oil-Free Compressors. Compressors which do not employ lubricating oil in the compressing elements so that lubricating oil doesn’t come in contact with the air during the compression process. (Oil-free compressors in Navy service include HP and LP reciprocating compressors, water-ring compressors, water-flooded screw, and centrifugal compressors.)

z. Portable Compressors. Machines consisting of a compressor and driver mounted so that they may be readily moved as a unit.

aa. Priority Valve. A valve installed between the vital and nonvital service air mains which, by cutting off the airflow to the nonvital air services when the pressure in the vital air main drops below a set value, renders the ship’s total air capacity to vital service demands only.

ab. Relay Tank. A pressure vessel used to minimize pressure fluctuations in a gas ejection system for guns.

ac. Reciprocating Compressors. Positive displacement machines in which the displacing and compressing elements are pistons moving back and forth in a cylinder fitted with suction and discharge valves.

ad. Rotary Compressors or Blowers. Positive displacement machines in which the displacing and compressing elements are interacting lobes, screws, or eccentrically-oriented vanes rotating within housings fitted with suction and discharge ports.

ae. Standard Air. Air at a temperature of 65° F, a pressure of 14.7 lb/in^2 absolute, a relative humidity of 36 percent, and a weight density of 0.0750 lb/ft^3 .

af. Starting Air Flask. A pressure vessel for storing compressed air used for starting diesel engines and gas turbines.

ag. Vital Services. Services for which continuous compressed air availability is essential for safety, propulsion, survivability, and mission capability of the ship.

551-1.3 COMPRESSOR INTAKE AIR

551-1.3.1 GENERAL. Intake air for compressors usually is taken from the space in which the compressor is located. Whether the intake air source is from the space or from the weather, it is extremely important that spray, rain, water, or combustible vapors from the use or spillage of combustible materials do not enter the air intake. Combustible materials not only contaminate the air but produce highly explosive mixtures readily ignitable within an operating compressor. It is important to the operation and life of the compressors that intake air be as relatively cool, dry, and clean as conditions permit. Intake air filters are provided on all compressor air intakes as the primary means of providing relatively clean intake air.

551-1.3.2 COMPRESSOR INTAKE FILTERS. The area or space at the compressor intake is constantly under vacuum while the compressor is in operation. If the cleanliness at the compressor intake area is not maintained, vast quantities of dust, dirt, and grit will be taken into the compressor. When these contaminants are allowed to enter the compressor, they have an abrasive effect on all internal air passage components. The only way of reducing this internal wear and resulting maintenance expense is through the use of an intake filter. There is a wide variety of filter designs including the following:

a. Dry Type Filters which have felt or other filtering media held in rectangular or radial fin forms. Some types include a silencer chamber to reduce the noise of intake pulsations. This is the only type filter suitable for use on oil-free compressors.

b. Viscous Impingement Types, rectangular or cylindrical, packed with fine strands of wire coated with oil. The oil film traps dust.

c. Oil-Bath Filters have a reservoir of oil agitated by incoming air. Oil-coated dust collects in the reservoir.

d. Air compressors that service Total Protection (TP) zones on Collective Protection System (CPS) equipped ships must be fitted with Chemical, Biological and Radiological (CBR) filters if the compressor intake air is taken from outside the zone. Each CBR filter consists of three concentric cylindrical filters: a prefilter, a HEPA filter and a charcoal gas absorbent filter. In a CBR environment, the filter will purge the intake air of chemical agents to prevent the compressor from contaminating the TP zone. CBR filters may be dedicated or canister type units installed directly on the associated compressor suctions, or they may be arranged in a plenum configuration with individual branch lines serving each compressor. In either case, a ventilation terminal shall be located within 18 inches, but no closer than 6 inches from the inlet of the CBR filter. Finally, differential pressure indicators are required to indicate when CBR filter changeout is required. See Technical Manual SS200-AG-MMM-010 for further information on CBR filters.

551-1.3.2.1 Many intake filters now being used are of the disposable type (refer to the applicable technical manual for proper maintenance). It is imperative that the air intake filter for an oil-free compressor be maintained completely free of oil.

551-1.4 AIR FLASK TYPES

551-1.4.1 HIGH PRESSURE AIR FLASKS. Since 1962, flasks have been fabricated according to MIL-F-22606. These later flasks are a nonshatterable type suitable for any shipboard application. They can be spherical, straight cylindrical or curved banana-like cylinders, or of the moisture separator flask design. Internal corrosion is severe in moisture separator flasks and in air bank flask neck and end plugs. Flasks installed in submarine ballasts tanks may show external corrosion, particularly in areas where inaccessibility prevents proper cleaning and painting. Standard flask sizes are given in Table 551-1-1.

Table 551-1-1 STANDARD FLASK SIZES

Class and Type	Capacity (Min)	Outside Diameter ± 3/32 inch	Length (+ 2 inches -0 inch)	Wall Thickness (Min)	Weight (approx)	Hydro-Test Pressure
	Cubic Feet	Inches	Feet-Inches	Inches	Pounds	
Class 3,000						
Type GF	4.0	18	3 - 11	.561	450	5,000
Type GF	6.0	18	5 - 3	.561	615	5,000
Type GF	8.0	18	6 - 7	.561	800	5,000
Type GF	10.0	18	7 - 10	.561	915	5,000
Type GF	15.5	18	11 - 6-1/2	.561	1,350	5,000
Type GF	21.0	18	15 - 2	.561	1,770	5,000
Type CD	21.0	18	15 - 2	.561	1,770	5,000
Class 5,000						
Type SF	.5	6-5/8	3 - 10	.494 (1)	140	8,330
Type GF	1.5	10-3/4	4 - 2	0.572 (1)	305	8,330
Type GF	4.0	18	4 - 3	.933	850	8,330
Type GF	6.0	18	5 - 8-1/2	.933	1,135	8,330
Type GF	8.0	18	7 - 2	.933	1,415	8,330
Type GF	10.0	18	8 - 8	.933	1,705	8,330
Type GF	10.0	20	7 - 4	1.028	1,715	8,330
Type GF	15.5	18	12 - 8-1/2	.933	2,480	8,330
Type GF	21.0	18	16 - 9	.933	3,260	8.330
Type CD	21.0	18	16 - 9	.933	3,260	8,330
Type GF	25.0	20	16 - 3	1.028	3,820	8,330
Type CD	25.0	20	16 - 3	1.028	3,820	8,330

Note

1. All 1/2 ft^3 capacity separators (type SF) and 1.5 ft^3 (type CF) flasks shall be class 5,000 and shall be applicable to all pressures up to and including 5,000 lb/in^2 .

551-1.4.2 MOISTURE SEPARATOR FLASKS. Moisture separator flasks are devices for collecting and removing moisture, which precipitates out as water from the air or gas during the process of cooling. The HP air system moisture separator flasks shall be blown down (as directed in paragraph 551-1.12.1.2.1) hourly by ship's force whenever the compressor is in operation. If two compressors are charging through one moisture separator flask, blowdown every 1/2 hour is required.

551-1.5 AIR RECEIVERS

551-1.5.1 INSTALLATION. An air receiver is installed in each compartment containing MP and LP air compressors (except for high capacity, centrifugal compressors on CV/CVN's). Some receivers are equipped with automatic drain valves which should be checked periodically according to Planned Maintenance System (PMS) requirements to ensure proper operation. Receivers provided with manual drain valves shall be drained approximately after each 200 hours of service or more frequently if necessary. The purposes of receivers are:

a. To help eliminate pulsations in the discharge line of the compressors plus providing a stable pressure sensing station for compressor control.

b. To act as a storage tank during intervals when the demand for air exceeds the capacity of the compressor such as providing the amount of air for the required number of starts for diesel engines.

c. To enable the compressor to shut down during periods of light load. The volume of existing air receivers for LP and MP compressors may be as low as 1/5 the combined free air capacity per minute of the compressors located in the respective compartment.

551-1.5.2 AUTOMATIC OPERATION. Most of the older oil-lubricated compressors are equipped with automatic start-stop operating controls and sufficiently large receiver capacity so that the compressor start-stop cycle duration is long enough to prevent motor overheating from too frequent starting. The new oil-free LP air compressors are equipped with automatic load-unload controls which eliminate frequent motor starting so that only small nominal receivers are provided.

551-1.5.3 MOUNTING. The air receivers may be either horizontal or vertical, their position and location being dependent on the space available for their installation. Vertically-mounted receivers should have bottom heads of convex shape to permit accumulations of moisture, oil, and foreign matter to drain properly.

551-1.5.4 ACCESSORIES AND CONNECTIONS. Each air receiver should include the following accessories and connections.

a. Valved inlet and outlet connections with a valved bypass

b. Drain connection and valve

c. Connection for operating line to compressor control system

d. Pressure gauge

e. Relief valve

f. Manhole (11-inch by 15-inch oval if the size permits) or handhole plate depending on size of receiver to permit complete cleaning.

551-1.5.4.1 The inlet and outlet connection to the system mains should be located near the top of the receiver. The discharge line between the compressors and receiver should be kept as short and as free from bends as possible in order to eliminate excessive vibration due to the pulsations of air and to reduce pressure loss. The relief valve is installed on the receiver without intervening valves, to prevent any excessive pressure rise within the receiver in the event compressor unloading devices or pressure controls fail to function properly.

551-1.5.4.2 The specific setting of the relief valve will depend upon the characteristics of the valve as well as the nominal operating pressure of the receiver; however, in all cases the setting shall be high enough to permit the valve to reset tightly after relieving an overpressure. A setting of 12 percent above the nominal operating system pressure is recommended in the event the proper setting cannot otherwise be determined. The relief valve shall be tested according to PMS requirements by lifting the hand lever, if one is provided, or by raising the system pressure required to lift the valve.

551-1.5.5 RECERTIFICATION. All LP and MP air receivers under the cognizance of the Naval Sea Systems Command (NAVSEA) shall be recertified during the sixth year of service and at intervals of approximately six years thereafter. Recertification assures satisfactory receiver strength to support system operation for an additional six years and assures satisfactory receiver operation; receiver drain lines that continue to operate freely. If the receiver is contaminated with hydrocarbons, clean in accordance with MIL-STD-1622. The following procedure shall be followed for ferrous receivers:

1. Clean and inspect internal and external surfaces for pitting.
2. Weld repair all pitting below minimum wall thickness as specified by the receiver detail drawing.

NOTE

If the receiver detail drawing does not provide a minimum wall thickness allowance for corrosion, minimum wall thickness for recertification shall be 90 percent of the original specified material thickness.

3. Represerve receiver surfaces as required according to original detail drawings or as follows:
   a Internal surfaces.
      (1) For receivers which do not supply breathing air, hand or mechanically prepare deteriorated areas (corrosion, rust, delaminated paint, etc.) to sound paint or bare metal. Feather the edges of surrounding coating. Apply one coat each of Formula 150 and 152 (MIL-P-2441, 2-3 mils dry-film thickness (DFT) per coat) or MIL-P-23236 two-coat epoxy system (2-3 mils DFT per coat) to the prepared area. The color of the final coat shall be white.
      (2) For receivers which supply breathing air, with the exception of those used in a diver's life support system, prepare deteriorated area (corrosion, rust, delaminated paint, etc.) to near-white-metal finish (SSPC-SP-10). Apply one coat of zinc rich primer (DOD-P-24648 Ty 1, C1 1, Comp. B, 3-5 mils DFT) to the prepared surface.
   b Exterior surfaces. Paint same as the surrounding structure.
4. Hydrostatically test the receiver to 1-1/2 times the nominal operating system pressure and hold for 5 minutes. There shall be no visible permanent deformation.

551-1.6 AFTERCOOLERS

551-1.6.1 As system air quality requirements (moisture content) became more stringent, aftercoolers were provided between the compressor's final stage of compression and the air receiver. The purpose of the aftercooler in conjunction with a separator is to remove moisture from the compressed air immediately after compression before the air enters the receiver, and to reduce the temperature of the air to acceptable levels. This is accomplished by lowering the temperature of the air from the compressor and thereby condensing additional water vapor which can then be removed by a separator. Reducing the temperature of the air allows a greater mass of air to be stored in a given volume. Since aftercoolers are generally integral with the compressor, they will be described more fully in connection with the various types of compressors. Aftercoolers also serve to reduce the performance requirements of dehydrators (saturation temperature and moisture removal capacity) when installed.

551-1.7 COMPRESSOR DISCHARGE HP AIR FILTER

551-1.7.1 Oil-lubricated HP air compressor complexes incorporate oil/particulate air filters in their discharge piping. The most commonly used filter for this purpose is the Cuno 1H1 type, usually installed downstream of the moisture separator. The main purpose of this filter is to remove dust and particulate matter which pass through the compressor air intake filter, and any carryover of the lube oil used within the compressor moving parts. This filter provides maximum safety against air system fires and explosion hazards by minimizing lube oil deposits and accumulations within the piping system.

551-1.8 COMPRESSOR DISCHARGE AIR QUALITY

551-1.8.1 GENERAL. All air compressors discharge air in the fully saturated (moisture-laden) condition at some elevated pressure. Compressed air, when contaminated with water and moisture, damages and impedes proper operation of system components. An effective way to deal with this problem is to remove most of the water and moisture immediately at the compressor discharge.

551-1.8.2 MOISTURE REMOVAL. The bulk of the water and moisture is removed by installing water traps with drains (moisture separators) and air-cooling or drying devices with drains (aftercoolers and dehydrators). All of these devices shall be periodically drained manually or by an automatic condensate drain system to be effective. If not properly drained, the remaining condensed moisture (water) will reenter the airstream by flashing back into a vapor as the compressed air is used and the pressure is lowered in the compressed air piping throughout the ship. Low-point drains are installed at suitable locations throughout the ship's compressed air system piping.

551-1.8.2.1 For services and functions which require air with a lower dew point than that provided by the source compressor complex, additional moisture (water) removal devices (dehydrators) are installed as necessary to meet these requirements. Instruments (dew point indicators) are provided for measuring and monitoring the performance of the air dehydrators.

551-1.8.3 AIR QUALITY CONTROL. Air quality control may be maintained as follows:

1. Inspect cooler outlet temperatures and separator drain devices.
2. Inspect and clean or replace dehydrator filters according to the applicable PMS requirements or as specified in the applicable technical manual.
3. Check and reset, if necessary, back pressure regulating valves (if installed) according to the applicable PMS requirements or as specified in the applicable technical manual.
4. Replace dehydrator desiccant according to the applicable PMS requirements or as specified in the applicable technical manual (see paragraph 551-4.5.9).

551-1.8.3.1 The air dehydrator air-drying capability shall be monitored by taking air dew point temperature readings of the effluent air at the sample test connection in the discharge side of the dehydrator, as follows:

a. Frequency of dew point temperature readings. A dewpoint temperature reading for submarines shall be taken at least every 6 months during scheduled inport maintenance and for surface ships, every 4 hours of service.

b. HP air dehydrator point temperature readings. A dew point temperature reading of -60° F or lower at atmospheric pressure shall be delivered by the air dehydrator. A dewpoint temperature reading higher than -60° F at atmospheric pressure normally indicates dehydrator malfunction or improper operation (check applicable dehydrator technical manual).

c. LP air (type I) dehydrator dewpoint temperature readings. A dewpoint temperature reading of 40° F or lower at 80 lb/in^2 indicates that the air dehydrator is delivering an air quality within its design capability. A dewpoint temperature reading of 50° F or higher at 80 lb/in^2 indicates dehydrator malfunction or improper operation (check applicable dehydrator technical manual).

d. LP air (type II and type III) dehydrator dewpoint temperature readings. A dewpoint temperature reading of -40° F or lower at 80 lb/in^2 indicates that the air dehydrator is delivering an air quality within its design capability. A dewpoint temperature reading of -20° F or higher at 80 lb/in^2 indicates dehydrator malfunction or improper operation (check applicable dehydrator technical manual).

551-1.8.3.2 Ensure air dehydrator prefilters are blown down as required by applicable equipment manuals.

551-1.8.4 THEORETICAL APPLICATION. Figure 551-1-1 is a useful aid in understanding what happens to the water vapor content of air when processed in a compressed air system. When atmospheric air (even though at a very low relative humidity) is compressed, it becomes saturated with water vapor and droplets form. This saturation is caused by the decrease in volume with the resultant increase in partial pressure of water vapor.

551-1.8.4.1 Referring to Figure 551-1-1 , it can be seen that if atmospheric air at 70° F with a dewpoint of 0° F is compressed to 4,500 lb/in^2 , the temperature of the air would have to be raised to nearly 150° F to prevent saturation and condensation. At the design ambient temperature of 100° F and 30 percent relative humidity, the dewpoint temperature is 64° F. Under these conditions, the air contains .0128 pounds of water per pound of dry air. This air is discharged by a compressor at 100° F.

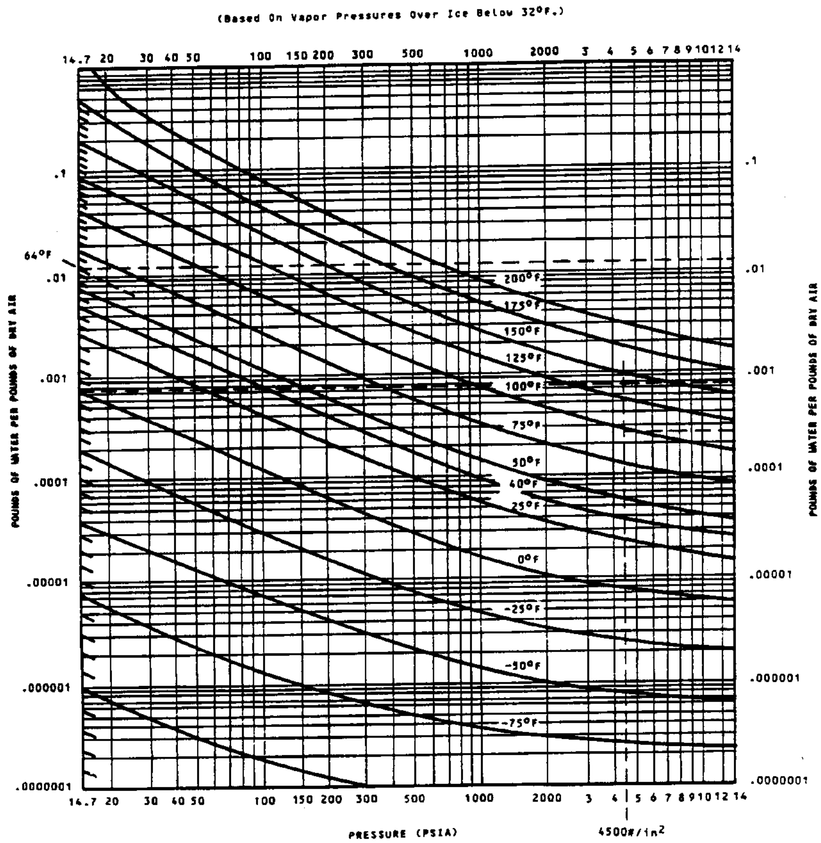


Figure 551-1-1 Water Content of Saturated Air

551-1.8.4.2 If the air is assumed to be saturated, the absolute humidity is about .00025 pounds of water per pound of dry air at 4,500 lb/in^2 pressure and about .00035 pounds of water per pound of dry air at 3,000 lb/in^2. Thus, there shall be a net reduction in moisture content of about .01255 pounds (.01280-.00025) of water per pound of dry air when air is passed through a 4,500 lb/in^2 compressor and about .01245 pounds (.01280-.00035) of water per pound of dry air when air is passed through a 3,000 lb/in^2 compressor. (The water that condenses is removed by the separators installed on the compressor between stages and on the discharge.)

551-1.8.4.3 It would seem that with such a low absolute water content, further removal of moisture would not be required. However, since air may be stored in flasks in unheated spaces or in ballast tanks where water temperatures can get as low as 28° F, it is possible for water, in the form of condensation, to appear again.

551-1.8.4.4 The amount of moisture removed or condensed from 100° F at 4,500 lb/in^2 to 28° F at 4,500 lb/in^2 is very small. However, over a long period of time this small amount of moisture that is contained in each pound of air could accumulate in sufficient quantity in the air flasks, and if not drained periodically, will reenter the air system upon the use of air from the air banks. If a substantial quantity of this stored HP air is suddenly reduced to a much lower pressure over a short period of time, freezing within the system can occur to cause temporary malfunction of the subjected components.

551-1.8.4.5 The most practical means of moisture removal is the use of a dehydrator at the compressor discharge. The desiccant type of dehydrators generally use activated alumina as drying agents. Most HP air dehydrators are not fully automatic (some automatic HP dehydrators have been installed on aircraft carriers). Extreme care shall be used when performing the proper sequence of operation of this equipment. HP dehydrator desiccant towers shall be shifted regularly. During normal operation, one tower is in service while the other is being reactivated. Refer to Section 4 for a description, operating procedures, maintenance, and test of the various types of dehydrators installed on ships of the U.S. Navy.

551-1.9 PIPING

551-1.9.1 MATERIAL. The more recent years have seen a change in the piping material used in air systems. The use of stainless steels, where there is no contact with seawater, has increased with corresponding increases in system air pressures because of its relatively greater strength, its availability, weldability, cleanliness, and workability. Air systems that are located in or pass through fire hazardous areas are being welded rather than silver-brazed for safety reasons. Silver-brazed copper piping is still extensively used in LP and MP air systems having no seawater contact. Where air system piping is subjected to seawater corrosion, copper-nickel (90-10 or 70-30) piping is used.

551-1.9.2 INSTALLATION. Each piping system should be complete in all respects with gauges, valves (stop, check, relief, reducing), drainage arrangement, pressure controls, flasks, receivers, strainers, filters, and moisture separators. Piping is arranged to eliminate pockets where moisture may collect. Where pockets or low points exist, drains are provided.

551-1.9.2.1 Dead-end piping is kept to a minimum. Piping is generally located to take advantage of all the protection which may be available such as bulkheads, trunks, and other structures. In particular, air piping which supplies vital services should be located to take advantage of any ballistic protection and the water side protective system if provided. Valves are installed to permit isolation of damaged portions of the system and to provide maximum flexibility in operation.

551-1.9.2.2 When automatic drains are not provided, manual bleed connections are provided with needle valves to permit a slowly controlled depressurization or drainage of the system. High-pressure bleed connections are installed with double-valve protection. Bleed-down discharges are located so as not to endanger personnel when bleeding down the air system.

551-1.9.2.3 Discharge piping from relief valves is directed so as not to damage machinery or equipment or endanger personnel. Gauge lines are provided with a bleed-off plug on the cutout valve or between the gauge and the gauge cutout valve. This bleed-off plug provides a means of slowly releasing the air which may be trapped between the gauge and the gauge cutout valve without completely removing the plug.

551-1.9.2.4 Automatic safety-stop check valves are installed immediately upstream of each hose connection which supplies air at a constant pressure above 150 lb/in^2 .

551-1.9.2.5 Automatic shutoff valves act as safety devices to secure the airflow when a downstream rupture occurs. Automatic shutoff occurs as the result of the pressure drop when rupture occurs.

551-1.9.3 OPERATIONAL PROVISIONS. Air system piping shall incorporate provisions to ensure the following:

a. Means for bleeding down for repair purposes.

b. Means for bleeding down trapped air at hose connections, which are pressurized above 125 lb/in^2 , before disconnecting.

c. Drain line terminals on components such as air flasks, separator flasks, filters, and low-point drains shall be located so that the discharge is clearly visible to the operator and directed to prevent injury to personnel and equipment. It shall also lead to a convenient space deck drain or appropriate drain collecting system by way of an open funnel.

d. Means for testing the automatic shutoff valve for normal functioning as well as for checking the automatic shutoff features.

e. Accessibility for resetting, testing, and overhauling automatic shutoff valves.

f. Ease of inspection and cleaning of piping, air flasks, and other components.

g. Means to prevent rapid air-pressurization which causes excessive temperatures.

h. Means to isolate damaged portion of systems and provide maximum flexibility in operation.

i. Minimum deposits of lubricants in piping, air flasks, and other components.

j. Means for operating inaccessible system valves through the use of extension rods.

551-1.10 TAKEDOWN JOINTS

551-1.10.1 Mechanical connections such as flanges and unions in air systems with pressure of 200 lb/in^2 and over shall use O-ring seals. Nitrile (Buna-N) O-rings are to be avoided in air systems due to the high number of seal failures resulting from increased hardness and embrittlement of the rubber O-ring after long-term aging in service. High leakage in HP air systems is found to significantly increase HPAC usage and therefore maintenance costs. In accordance with NSTM Chapter 078, fluorocarbon (90 durometer) shall be the typical material used for HP system O-ring seals. O-rings in systems controlled by NAVSEA 08 shall be as directed by NAVSEA 08.

551-1.11 LUBRICATION

551-1.11.1 For the proper selection of lubricants and thread compounds in air systems 1,500 lb/in^2 pressure and above, refer to NSTM Chapter 262, Lubricating Oils, Greases, Specialty Lubricants, and Lubrication Systems.

551-1.12 MAINTENANCE OF AIR SYSTEM EQUIPMENT AND COMPONENTS

551-1.12.1 AIR SYSTEM MAINTENANCE. The following maintenance applies to systems with either oil free or oil lubricated compressors.

551-1.12.1.1 Inspection. All air flasks, receivers, separators, and piping shall be surface inspected to determine whether flasks or piping are damaged or externally corroded. In submarines, these components shall be surface inspected at each dry-docking; in surface ships every 6 months. Inspection date and results shall be entered in the Maintenance Material Management (3M) System.

551-1.12.1.2 Maintenance Procedures. Strict adherence to the maintenance procedures contained in the following paragraphs will ensure maximum safety during operation of all air system components.

551-1.12.1.2.1 Blowdown. Regardless of air pressures, all accumulators, separators, filters, receivers, and air flasks shall be blown down (purged) to remove deposits of water and oil. The following steps shall be followed to ensure normal blowdown of these components, if double-valved, starting with both the upstream valve and the downstream valve closed.

1. Crack open the downstream valve.
2. Open the upstream valve to the bleed position for 10 to 20 seconds. If the valve does not have a bleed position, then crack open for 10 to 20 seconds.
3. Slowly open the upstream valve to the full open position.
4. After condensate and oil have drained, slowly close the downstream valve.
5. Close the upstream valve.

551-1.12.1.2.1.1 Frequency of blowdown shall be as follows:

a. Before placing system in operation.
b. Every week (when in operation), except equipment in the vicinity of air compressors. Equipment near compressors shall be blown down as specified below.
   1 Moisture separators installed downstream of the compressor discharge shall be blown down once per compressor hour of operation; that is, if two compressors discharge to a single moisture separator, blowdown shall occur once every 1/2 hour during the operation of both compressors.
   2 Oil or particulate filters installed downstream of moisture separators shall be blown down once per compressor hour of operation. Blowdown shall be more frequent if quantity of blowdown fluid exceeds approximately 1 cup in a blowdown period.
   3 Manually-drained compressor separators shall be drained every 15 minutes during operation unless experience dictates a different schedule. Compressors equipped with automatic separator blowdown shall be checked periodically to assure that the automatic blowdown is operating. However, if automatic separator blowdown is inoperative, the compressor may be operated in an emergency situation and must be drained every 15 minutes during operation.

551-1.12.1.2.2 Filter Inspection. If the installation includes dehydrators and integral filters, the filters on the upstream side of the dehydrators shall be depressurized and inspected every 200 hours of compressor operation. If these upstream filters show evidence of oil carryover, the filters on the downstream side of the dehydrator shall be isolated, depressurized, and inspected. If the downstream filter shows evidence of oil carryover (more than a light film), the desiccant in the towers should be replaced with fresh desiccant. Filter head outlet parts and other internal parts on the outlet side of the filter shall be wiped with clean absorbent paper as an aid in detecting oil carryover. Filter elements shall be changed whenever filters are checked.

551-1.12.1.2.3 Pressure Gauges. If pressure gauges are removed for calibration, repair, or replacement, the following procedure shall be used:

1. Observe normal system tag-out procedures.
2. Shut the root valve.
3. Shut the gauge valve.

4. Crack gauge valve test connection or bleed-off plug between gauge valve and gauge to relieve trapped pressure.
5. Disconnect gauge connection.
6. Remove gauge from gauge board.
7. Clean and calibrate gauge according to NAVSEA OD 45845.

551-1.12.1.2.3.1 Installation of gauge shall be as follows:

1. Mount gauge on gauge board.
2. Connect gauge to piping connection.
3. Perform leak test and in-place calibration check using applicable MCR procedure.
4. Open gauge valve.
5. Slowly open root valve.

551-1.12.1.3 O-Rings. O-rings should be in accordance with 551-1.10.

551-1.12.2 OIL LUBRICATED COMPRESSOR MAINTENANCE. The following maintenance applies to systems with an oil lubricated compressor only.

551-1.12.2.1 Fire and Explosion Prevention. Air compressors that are lubricated in the piston or cylinder area present an oil hazard in the discharge air piping. The accumulation of metal particles, carbon, and oil in the intercoolers, aftercooler, and associated interconnecting piping may result in piping fires and explosions. Accumulations of dirt, scale, and marine growth on the water side of water-cooled air coolers and compressor cylinder jackets result in elevated air temperatures and thus may also create a fire or explosion hazard. Regular periodic cleaning of the air and water passages of the compressor is therefore mandatory for safe and reliable compressor operation (see paragraph 551-1.17.1).

551-1.12.2.1.1 Oil Removal Filters. Separators and filters installed immediately downstream of the air compressor, when properly maintained, are effective in removing a high percentage of oil normally discharged by an oil-lubricated compressor. However, some oil will enter the piping system and accumulate since filters cannot be 100 percent effective. Refer to paragraph 551-1.16.2 for procedures for inspecting and monitoring the cleanliness of air piping systems and components downstream of oil and moisture separating apparatus and for the level of oil contamination which, when reached, requires systematic cleaning of the system and components.

551-1.12.2.1.2 Oil Accumulation in Air Piping. The air piping system between the compressor discharge connection (aftercooler discharge connection) and the oil and moisture removal devices will normally experience a constant low level oil input. The rate of oil input is principally a function of the cylinder lubrication rate and the thoroughness and regularity with which the compressor intercooler separators and aftercooler separator are blown down. However, the accumulation of foreign matter in this discharge piping will impede flow and will lead to a buildup of deposits which may present a fire and explosion hazard.

551-1.12.2.1.3 Cleaning of Air Piping. The deposits are also subject to degradation of their ignition properties due to exposure to high temperatures, airflow, and contamination. The result of such degradation may be a drastic reduction in their ignition temperature. Regular periodic cleaning of this piping is therefore necessary.

551-1.12.2.1.4 Auto-Ignition. Explosions and fires in air systems are known to have been caused with the presence of oil in the piping by rapid pressurization of dead-ended piping, or rapid valve closure which cause auto-ignition. These hazards can be prevented by minimizing hydrocarbon contamination in the compressed air piping and by observing appropriate operating, blowdown, and pressurization procedures and precautions. Procedures and precautions herein have been established through extensive laboratory tests and shall be rigorously observed. Their purpose is to provide maximum safety against air system fire and explosion hazards by preventing lube oil deposits and accumulations.

551-1.12.2.2 Maintenance Procedures. Strict adherence to the maintenance procedures contained in the following paragraphs will ensure maximum safety during operation of all air system components.

551-1.12.2.2.1 Lubrication. To minimize oil carryover into the air piping system, air compressor lubrication rates shall be kept to the minimum recommended by either the compressor technical manual or the applicable PMS Maintenance Requirement Card (MRC).

551-1.12.2.2.2 Filters. Only Cuno Micro Clean filter cartridge No. 2278-B2 or U78-B2 shall be used (except for diver's air systems, for which Pall elements and MDC 1001SUM or MDS 1001SUM have also been approved). All Cuno filters used to remove oil in compressor discharge lines shall be installed with inside-to-outside (reverse) flow. The filter element shall be replaced every **200** compressor hours of operation if the flow is from inside to outside or every **50** hours if the flow is from outside to inside. The filter element shall be replaced more often if oil carryover from the filter is excessive. If installed, the dehydrator prefilter may be examined as an aid in judging excessive oil carryover.

551-1.12.2.2.3 HP Air Piping System. The HP air piping system shall be inspected for oil contamination every 36 months, at overhaul periods, and whenever oil contamination is suspected. When inspection results indicate more than a light film coating of oil in the piping or components, the system shall be cleaned according to paragraph 551-1.16.3. A light film coating (approximately .1 mil thick is that which remains on the surface when an oil-coated surface is wiped off with a rag). Oil film coatings in excess of 1-mil thickness are considered hazardous.

551-1.12.2.2.3.1 The compressed air system inspection shall include collection and examination of blowdown from all HP air flasks, separators, low-point drains, and other system components, and by the disassembly of selected piping sections and components downstream of the compressor discharge. The system shall be blown down, according to paragraph 551-1.12.1.2.1, to a clean container until air begins to escape. Blowdown sample shall be allowed to settle and shall then be examined for oil content.

551-1.12.2.2.3.2 Representative piping sections and components downstream of the ship's oil-removal filter shall be selected for disassembly and inspection. Piping sections at the compressor discharge between the compressor and the supply side of the oil filter, and those with low points or pockets, are most likely to collect lubricating oil. If these selected samples are free from oil, it may be assumed that the remainder of the system is oil free.

551-1.13 SAFETY PRECAUTIONS

551-1.13.1 The following precautions apply to systems using both oil free and oil lubricated compressors:

a. Avoid rapid operation of manual valves. The heat of compression caused by a sudden high-pressure flow into an empty line or vessel can cause an explosion if oil is present. Valves shall be slowly cracked open until airflow is noted and should be kept in this position until pressures on both sides of the valve have equalized. The rate of pressure rise should be kept under 200 lb/in per second, if possible. When design pressure is reached, valves should be opened fully.

b. Never use combustible cleaning solvents (carbon tetrachloride) for cleaning compressor parts or where they may be drawn into the compressor intake.

c. Avoid the application of heat to the air piping system or components, and avoid striking a sharp or heavy blow on any pressurized part of the piping system.

d. Take appropriate precautions to ensure against contamination of the ship's air system when charging from a tender or shore system (see paragraph 551-1.15.1).

e. If pressure gauges are removed for calibration or other reasons, follow the procedure outlined in paragraph 551-1.12.1.2.3.

f. Never test HP gauges in a deadweight tester that uses oil as a fluid, since even a minute amount of oil remaining in the Bourdon tube of the gauge represents a potentially dangerous situation. Use a comparator-type gauge tester.

g. Do not install a stop valve or check valve between the compressor and receiver unless the compressor is fitted with a relief valve. Otherwise, if the compressor is started against a closed valve or an improperly installed check valve, serious damage can result.

h. After starting the compressor, never leave the compressor station unless the control, unloading, and governing devices are working properly. This precaution is especially important when starting a new compressor or one that has not been used for some time.

i. Never attempt to stop or repair an air leak while the leaking portion is still under pressure. Accidents have occurred as a result of disconnecting system parts still under pressure. To avoid this, always leave pressure gauges open to the pressure source to which they are attached. Before working on or removing any part of the compressor, make sure that:

    1 The compressor is electrically secured and tagged out.

    2 The compressor is completely blown down and pressure relieved.

    3 Valves between the compressor and receivers are closed, including the control or unloading valves (see Section 4).

    4 Double valve protection has been provided to isolate the depressurized area under repair.

j. To prevent damage resulting from overheating, maintain proper cooling water circulation and ensure that temperature cutout and monitoring devices are installed and working.

k. If a compressor exposed to freezing weather is to remain idle for any length of time, thoroughly drain the compressor circulating water system. This is not applicable to compressors with closed cooling water systems which should be filled with a 50:50 antifreeze-water mixture at all times for corrosion reasons, even if freezing is not possible.

l. Drain and blowdown equipment according to paragraph 551-1.12.1.2.1.

m. Avoid the possibility of introducing a shock wave into a high-pressure line by sudden opening of a valve.

n. Do not operate fast-operating, remote-controlled valves if the ratio of upstream to downstream pressure exceeds five. Emergency Main Ballast Tank (EMBT) blow valves, EMBT actuating air valves, and engine starting air valves are exceptions to this normal safety practice.

551-1.13.2 The following precautions apply to systems using oil lubricated compressors only:

a. First and foremost, check to see if the compressor lubrication flow rate is adjustable. If so, the lubrication flow rate is to be periodically checked (adjusted as necessary) according to the compressor manual to minimize oil carryover into the compressed air system. Explosions in compressed air systems with pressures in excess of 250 lb/in may be caused by the presence of oil in the air piping or components of the system, the presence of oil vapor in the compressor or receiver, leaky or dirty air compressor valves, and dirty air coolers resulting in abnormally high temperatures and dust-laden intake air.

b. To minimize explosion hazards, operating personnel shall observe all practical operating safety precautions including the following.

   1 Inspect the compressed air system at overhaul periods or when oil contamination is suspected according to paragraph 551-1.12.2.2.3. When inspection indicates the presence of lubricating oil in the piping or components in amounts greater than a light film coating, the system shall be cleaned according to paragraph 551-1.16.3.

   2 Drain moisture separators and filters according to paragraph 551-1.12.1.2.1.

   3 Change the air filters according to paragraph 551-1.12.2.2.3.

   4 Maintain the air dehydrators according to paragraph 551-1.12.1.2.2.

   5 Drain the air flasks, receivers, and piping low points according to paragraph 551-1.12.1.2.1.

c. Check the compressor discharge for black, sooty deposits. These deposits indicate conditions that could or have resulted in an explosion within the system. When deposits are noted, inspect and service the system to ensure an oil-free condition (see paragraphs 551-1.12.2.2.2 through 551-1.12.2.2.3.2).

d. Monitor the system closely to ensure that excessive temperatures that could result in auto-ignition do not occur. Hot spots on piping or components (as determined by touch) should be investigated and corrected. Ensure that compressor high-temperature alarms and cutout valves are maintained in operative condition. Secure the compressor immediately if the temperature of air discharging from any stage exceeds the recommended maximum.

e. A hazard is created if air flasks or receivers are charged too quickly from a high-pressure air source. If this compression takes place so rapidly that the heat of compression generated does not have enough time to escape, the temperature of the air will rise. If there is atomized oil in the air or if there is any oil accumulation in the flask or receiver from previous use, the possibility of fire or explosion exists. The pressurization rate for high pressure flasks should be less than 65 PSI per second. At this rate, it would take about 70 seconds to charge a flask from atmospheric pressure to 4500 PSIG.

f. Avoid lube oil or other combustible carryover from the compressor and deposits in the diesel engine starting air system by strictly adhering to precautions herein and in air compressor technical manual. Maintain starting air piping and components, including the starting air valve on the engine, free of combustible deposits by thorough cleaning of oil and carbon at engine overhauls. Maintain starting air valve operation and tightness by cleaning and lapping seats if necessary. Valves should not be allowed to become sluggish from gumming or a weak spring. Observe maintenance instructions in the diesel engine manual. Shut the starting air supply isolation valve when the engine is running.

551-1.14 HIGH PRESSURE (HP) AIR FLASKS

551-1.14.1 RECERTIFICATION

551-1.14.1.1 Scheduling. Flasks shall be recertified at the following intervals:

a. The recertification interval for HP air flasks built to MIL-F-22606 is 20 years maximum with the following qualifications:

(1) The HP air system serving the flask must have a dehydration device installed capable of maintaining air in the flask at a dew point temperature of minus 60° F or lower at atmospheric pressure. A dehydration device must have been originally installed in the system, not added via SHIPALT, MACHALT, etc.

(2) The flask must have an adequate blowdown or drain connection for periodic removal of condensation.

(3) The flask must not be installed so that the axis of the lower access opening is inclined greater than 20 degrees from the vertical.

b. The recertification interval for all HP moisture separator flasks is 7 years maximum or as specified by a submarine class maintenance plan. If in-place recertification is impractical because of ship location (station) or availability, the separator flask shall be replaced with a new or recertified separator flask obtained from stock. Separator flasks are carried under NSN 1H8120-00-148-1042L1 (4.62 inch diameter neck) or 1H8120-01-348-5971L1 (4.25 inch diameter neck). The separator needing recertification shall be clearly tagged UNCERTIFIED.

c. The recertification interval for any HP flask installed so that the axis of the lower access opening is inclined more than 20 degrees from the vertical is 6 years maximum.

d. The recertification interval for any HP flask without an adequate blowdown or drain connection for periodic removal of condensation is 6 years maximum. A flask of double-ended design is considered to have an adequate blowdown or drain if the lower connection is used as a drain connection; a flask of single-ended design is considered adequate if it is installed with the opening down, with a low-point connection provided for condensate removal.

e. The recertification interval for any HP flask that does not have a dehydrator installed to remove the moisture necessary to maintain the dew point temperature of -60° F or lower at atmospheric pressure to ensure against condensation at system operating conditions is 6 years maximum.

f. A summary of the above recertification scheduling for MIL-F-22606 flasks is shown in Table 551-1-2. Recertification scheduling of older style flasks (MIL-C-15111, MIL-F-2809, 51F10) shall be in accordance with Table 551-1-3.

Table 551-1-2 MIL-F-22606 AIR FLASK RECERTIFICATION INTERVALS

With air dryers, adequate drainage, less than 20 degree inclination	20 years maximum
Moisture separator flasks	7 years maximum
Without air dryers or adequate drainage or greater than 20 degree inclination	6 years maximum

Table 551-1-3 MIL-C-15111, MIL-F-2809, 51F10 AIR FLASK RECERTIFICATION INTERVALS

Surface Ships (All)	
With air dryers	12 years max.
Without air dryers	6 years max.
Submarines	
Class	Periodicity
SSN 637, 640	14 years max.

551-1.14.1.1.1 Start of Flask Certification Period. For new flasks, the time between the manufacturer's hydrostatic test (date stamped on the flask) and the date the flask is put into service is considered storage time. This time period is not used to determine when the flask must be recertified. The flask certification period starts when the flask is put into service. For new ships, use the ship delivery date as the flask start of service date. This policy of starting the certification period when the flask is placed in service also applies to moisture separator flasks and storage flasks which have been recertified and held in storage with a low pressure internal nitrogen charge.

551-1.14.1.2 Testing. The flasks requiring recertification shall be tested by Ultrasonic (UT) Testing or Acoustic Emission (AE) Testing. Hydrostatic testing is being eliminated because it does not provide data on flask wall cracking which has been determined to be the primary failure mode. Hydrostatic pressure testing in accordance with 551-1.14.1.2.c. will be permitted until 31 December 1998 to allow local facilities to implement UT or AE testing procedures.

a. Ultrasonic Test Method. Flasks shall be tested using the procedures in Appendix A and Appendix C.

b. Acoustic Emission Test Method. Acoustic emission inspection technology has been evaluated and deemed suitable for flask recertification. However, equipment must be validated and test procedures approved by NAVSEA 03L and NAVSEA 03M prior to use of this method.

c. Hydrostatic Pressure Testing (Not acceptable after 31 December 1998). Class 3,000 and class 5,000 flasks shall receive a hydrostatic pressure test of 5,000 lb/in^2 and 8,330 lb/in^2 , respectively. The method of testing shall be one of the following:
   (1) Water Jacket and Direct Expansion Hydrostatic Test Methods. Both the water jacket volumetric expansion method and the direct expansion method of determining flask expansion and permanent set are acceptable. These methods are outlined in Pamphlet C-1, **Methods of Hydrostatic Testing of Compressed Gas Cylinders** , which can be obtained from the Compressed Gas Association, Inc., 11 West 42nd Street, New York, NY 10036. Flasks that show a permanent set in excess of 10 percent of the recorded total flask expansion shall be drilled to prevent further use and disposed of as scrap.
   (2) Dynamic Pressure Testing. Recertification pressure testing may also be conducted according to NAVSEA S9551-AM-MMM-010, Gas Flask, High Pressure, Dynamic Strength Test.

CAUTION

During hydrostatic pressure testing, the flask shall be arranged in a vertical position and filled with fresh water. Care shall be exercised to ensure that the flask, connecting piping, and pump are completely filled with water and that no air pockets or bubbles remain in the system. Pressure shall be applied with a positively controlled HP pump. A class 3,000 and a class 5,000 high-pressure air flask under test shall be subjected to a hydrostatic pressure of 5,000 lb/in^2 and 8,330 lb/in^2 , respectively, for a period of 5 minutes. Flasks passing the hydrostatic test shall be immediately dried to prevent rust formation.

551-1.14.1.2.1 Conditions for Use of Ultrasonic Test Method in Place. Flasks may be tested in place using the procedures of Appendix A and Appendix C provided that a minimum of 90 percent of the required area is covered for ultrasonic thickness measurements. If this minimum coverage requirement can not be obtained, the flask shall be removed from the foundation and tested.

551-1.14.1.3 Flask Marking. Flasks that successfully pass the above testing shall be permanently marked by stamping on the cylindrical portion of the neck not closer than 1/2 inch to the tangent at the root of the neck.

Such markings shall be made with a round bottom low stress stamp and shall not be over 1/16-inch deep. Stamps with characters greater than 1/4 inch in height shall not be used. The following information, as a minimum, shall be stamped on the neck of each flask:

Example of stamping

a. Recertification activity PSNS
b. Type of recertification UT, AE or HT
c. Recertification date (month-year) 10-95

551-1.14.1.4 Records. Upon satisfactory completion of testing, report the following data to the planning yard:

a. Ship name and hull number
b. Flask serial number
c. Flask MIL-SPEC
d. Flask shipboard location
e. Date of recertification
f. Type of recertification (ultrasonic, acoustic emission or hydrostatic water jacket/direct expansion or dynamic)
g. Activity performing test
h. Test pressure for hydrostatic test

551-1.14.1.4.1 The foregoing data along with all test data shall also be recorded on a NAVSEA A Sketch drawing and forwarded to the appropriate planning yard.

551-1.14.1.5 Recertified Flask Preservation. Flasks which satisfactorily complete testing must be preserved as follows:

a. Flasks that have undergone ultrasonic or acoustic emission testing with no severe internal corrosion suspected are not required to be represerved on the interior.
b. Flasks that have undergone ultrasonic or acoustic emission testing with severe internal corrosion suspected shall be inspected in accordance with paragraph 551-1.14.2.2. If corrosion is found, the flask shall be cleaned in accordance with paragraph 551-1.14.3 and represerved in accordance with paragraph 551-1.14.1.5.1.
c. Flasks that have undergone hydrostatic pressure testing shall be cleaned in accordance with paragraph 551-1.14.3, inspected in accordance with paragraph 551-1.14.2.2 and represerved in accordance with paragraph 551-1.14.1.5.1.

551-1.14.1.5.1 Acceptable represervation coatings for interior surfaces are:

a. Electrostatic powder epoxy coating per Uniform Industrial Process Instruction 0631-901. After two coats and final curing, total thickness shall be 0.004 to 0.006 inch.
b. Powdered Fluoropolymer (20-40 mils thick) per MIL-C-24782.

c. USS Supply No. 80-6887 organic zinc-rich primer or Valspar MZ7 (13-F-12) inorganic zinc-rich primer. Minimum dry film thickness for these zinc-rich primers shall be 0.002 inch.

Flasks used solely or primarily for breathing air shall be cleaned internally and coated with the powdered fluoropolymer listed above or phosphate coated in accordance with NAVSEA S6560-AB-MMD-010,Cleaning and Phosphate Coating Instructions, HP Air Flasks Used in Diving Systems.

551-1.14.1.5.2 If the exterior surface requires repainting, all dirt, rust, and loose paint shall be removed and the flask shall be primed. All flask exteriors shall be coated with either a zinc-rich primer in accordance with paragraph 551-1.14.1.5.1.c or zinc molybdate primer, TT-P-645. If overcoating is required, it shall be with haze gray alkyd enamel, MIL-E-24635.

551-1.14.1.6 Reassembly of End Plugs Into Flasks. When reassembling flasks according to MIL-C-15111 and MIL-F-2809, use a new copper gasket as shown on mechanical standard dwg 5000-S4902-431270. Coat plug threads and gasket and set with an approved thread coating listed in NSTM Chapter 262, and torque plugs to approximately 4,700 ft-lbs Test for leakage by charging with air at nominal operating pressure (zero leakage allowed). Assemble flasks furnished according to MIL-F-22606. Assemble seal-welded plugs without gaskets and torque to 800 (+200) ft-lbs Plugs with O-ring seals shall be torqued to 250 to 400 ft-lbs, followed by installation of friction band and clamp ring.

551-1.14.2 INSPECTION. The following information explains the procedures for inspecting the air flask.

551-1.14.2.1 External Inspection. At yearly intervals, submarine flasks located inside the pressure hull and all surface ship flasks shall be visually examined externally for signs of corrosion, dents, arc strikes, thread galling, and other damage. Submarine ballast tank flasks shall be visually examined during each drydocking of the submarine. Any flask showing evidence of burns from welding and cutting torches (other than superficial damage to paint coating) shall be rejected and drilled to prevent further use. Corrosion, gouges, dents, and nicks shall be closely examined to determine depth of defect. Any defect 1/16 inch or more in depth shall be cause for ultrasonic examination of the affected area to determine the remaining wall thickness according to the requirements of MIL-STD-271.

551-1.14.2.1.1 Defects, if sharp bottomed, shall be removed by grinding and fairing into the surrounding area with a taper of not less than 4 to 1, before ultrasonic inspection. If, during the ultrasonic inspection, the wall thickness at any point registers below the minimum acceptable wall thickness shown in Table 551-1-4, the flask shall be rejected and drilled to prevent further use. Damaged areas of satisfactory flasks shall be cleaned with a rotary wire brush and repainted with appropriate paint (see paragraph 551-1.14.1.5). Flasks with neck threads exhibiting galling to the extent that thread damage occurs and with neck outside diameter of 4.625 inches or more may be rebored and rethreaded for an oversized 2-7/8 or 3-inch plug.

551-1.14.2.2 Internal Inspection. Remove end plugs or fittings, and visually inspect flask interior by means of a borescope or droplight lowered through the 2-3/4 inch opening in the neck. (A 100 or 200 watt projection-type lamp is suitable for this size opening.) Note condition of paint and may evidence of internal degradation such as corrosion or pitting. If such evidence is found, mark the location on the outside of the flasks to facilitate ultrasonic inspection. Check flasks ultrasonically according to MIL-STD-271 to determine wall thickness, particularly in corroded or pitted areas. Wall thickness readings that are less than that allowed in Table 551-1-4 are cause for rejection of the flask.

NOTE

Any empty used flask for which inspection data is incomplete shall be inspected according to the foregoing before being charged.

Table 551-1-4 AIR FLASK SPECIFICATIONS

Specification	Working Pressure 1b/in^2	Diameter (Inches)	Minimum Wall Thickness (Inches)
51-F-5 or	3,000	5-1/4 ID	[1]
MIL-C-15111		16 ID	0.64 [4]
MIL-C-15111	5,000	5-1/4 ID	[1]
		16 ID	0.90 [4]
51-F-10 or	3,000	18 OD	0.50 [4]
MIL-F-2809	4,500 [2]	18 OD	0.773 [4]
		20 OD	0.896 [4]
MIL-F-22606	3,000	18 OD	0.50
MIL-F-22606	5,000	6-5/8 OD	0.40
		10-3/4 OD	0.51
		18 OD	0.83
		20 OD	0.90
MIL-F-21527	4,500	22-9/16 OD	1.185
MIL-F-24032 [3]	3,000	6-5/8 OD	0.375

NOTES:
1. Separator flasks of this design are obsolete and, if discovered in service, shall be replaced with a 0.5 ft^3 separator flask (MIL-F-22606).
2. MIL-F-2809, Modified for 4,500 lb/in^2 service.
3. MIL-F-24032 flasks are fabricated of K-monel and are intended for removal of KOH (potassium hydroxide) carryover from oxygen generators, MIL-F-24032 flasks are included here to make Table 551–1–4 complete and comprehensive.
4. Storage flasks of this design are obsolete and must be replaced with a flask in accordance with MIL-F-22606 when wall thickness is found to be less than minimum allowable.

551-1.14.2.3 Intermittent Inspection. If serious corrosion of a flask exterior or interior is suspected, inspections and testing shall be conducted before the next scheduled periodic examination. When suspected flasks are inspected and tested earlier than scheduled, one or more flasks in apparent good condition shall also be inspected. This is to ensure that no corrosion has taken place that is not detectable through in-place inspection.

551-1.14.3 CLEANING. The following paragraphs describe the procedures for cleaning air flasks.

551-1.14.3.1 Cleaning Requirements. After initial interior surface inspection, clean flask interior as needed by sandblasting, shotblasting, tumbling, or by chemical means when approved by NAVSEA. Clean flask exterior as needed by sandblasting or rotary wire brush. Blow all loose dirt and blasting material out of flask with clean, dry, compressed air. During cleaning operations, protect all thread areas against physical damage. Flasks used solely or primarily to provide breathing air shall be maintained according to NAVSEA S6560-AB-MMD-010, High-Pressure Diving Gas Storage Flasks. When specifically approved by NAVSEA, inaccessible high-pressure air flasks may be refurbished in-place according to instructions contained in NAVSEA 0900-LP-092-0010.

551-1.14.3.2 Postcleaning Inspection. Examine flask interiors and exteriors after cleaning to ensure that affected surfaces have been cleaned to bare metal. (Affected surfaces are those areas that initially exhibited corrosion, loose or blistered paint, or other contaminants.) If, after cleaning, the unaffected areas exhibit patches of paint that are well adhered to the metal surfaces, no additional cleaning is necessary to remove the paint.

551-1.15 CHARGING HP AIR FLASKS OR AIR BANKS FROM SHORE OR TENDER SIDE

551-1.15.1 The following procedures and precautions provide instructional guidance to charging facility and receiving ship for HP air flask charging operations.

551-1.15.2 The HP air furnished by tenders or shore activities shall be led to the receiving ship's moisture separator flask, filter, and dehydrator unit (when installed) to ensure dry, clean, oil-free air.

551-1.15.3 The following equipment, suitable for charging pressure, shall be provided (if not already installed) in the shore- or tender-based compressor discharge line in the order indicated.

a. A moisture separator flask according to MIL-F-22606 (valved)
b. A NAVSEA-approved air filter suitable for oil removal such as Cuno Model 1H1-2278 or equal.

551-1.15.4 The following equipment, shall be adhered to by the charging facility before each HP air flask charging operation.

a. New filter elements shall be installed.
b. Before the shore- or tender-piping is connected to the shipboard system, the compressor intercooler and aftercooler, the moisture separator, and the filter shall be blown down. The separator and filter shall be blown down once every hour during charging operations.
c. The charging hose or pipe shall be visually checked to ensure that it is free from oil, moisture, or other contaminants.

551-1.15.5 Receiving ship's responsibility before and during the HP air flask charging operations:

a. The receiving ship shall coordinate charging operations and shall ascertain that the shore activity or tender has fulfilled all the foregoing requirements.
b. Low-point drains, in system sections used for charging the air banks, shall be blown down according to paragraph 551-1.12.1.2.1. The receiving ship's moisture separator and filter shall be blown down before the charging operation and once every hour during the charging operation.
c. New filter elements shall be installed before the shore-or tender-charging operation.
d. The dehydrator discharge air shall be checked to ensure that a -60° F dewpoint temperature at atmospheric pressure (or lower) is being delivered.
e. On submarines, HP air banks shall be checked after a charge to ensure a dryness of -60° F dewpoint temperature (or lower) at atmospheric pressure.

551-1.15.6 If the ship's installed air processing equipment (such as a moisture separator, oil/particulate filter, and dehydrator) are not in normal operating condition, both ship and charging facilities have a responsibility to ensure that any air being charged meets the dewpoint and filtration requirements of the ship's installed equipment when in operating condition.

551-1.16 AIR SYSTEM

551-1.16.1 TESTS. The following are test procedures used in determining the operability of air systems.

551-1.16.1.1 Hydrostatic Pressure Test. The purpose of a hydrostatic pressure test is twofold:

a. It establishes that the system is externally leak-tight and provides an indication of the condition of the boundary valves.
b. It provides a certain level of assurance that overall deterioration or fabrication errors (including defects) do not exist.

551-1.16.1.1.1 The pressure used during a hydrostatic test is 135 percent of the system design pressure. However, for ships built before 1969, the hydrostatic test pressure shall not exceed that value specified on original system drawings or 150 percent nominal operating pressure, whichever is less. The testing medium shall be clean fresh water (do not use the cleaning medium) or air, if the test pressure does not exceed 75 lb/in^2 g. Instruments and equipment that might be damaged by clean fresh water shall be excluded from the hydrostatic pressure test.

551-1.16.1.1.2 A satisfactory hydrostatic pressure test is generally mandatory once the pressure boundary integrity of a piping system has been violated. This system violation and re-entry generally occurs whenever any work or repair (involving a fabrication process such as welding and silver-brazing) is done during system overhaul.

551-1.16.1.1.3 SeeNSTM Chapter 505 for alternatives to hydrostatic testing.

551-1.16.1.2 Pressure-Drop Test. Following the hydrostatic pressure test, the system shall be drained of all water, thoroughly dried (by blowing out with warm, dry air), and tested for tightness with air at nominal operating pressure. Test pressures of 1,000 lb/in^2 g or greater shall be maintained for a minimum of 24 hours. The maximum allowable static pressure drop during this period shall be equivalent to 1 percent of the test pressure. Test pressures below 1,000 lb/in^2 g shall be maintained for 6 hours minimum.

551-1.16.1.2.1 The maximum allowable static pressure drop during this period shall be equivalent to 5 percent of the test pressure. All data shall be corrected for air temperature difference at the beginning and end of the test.

551-1.16.1.2.2 If the maximum allowable static pressure drops are exceeded, the system shall be re-examined, leaks eliminated, and the piping retested.Do not tighten leaking mechanical joints until all pressure is removed. If leak repairs introduce foreign matter into the system, the sections affected shall be recleaned before the test is repeated.

551-1.16.1.3 Dynamic Tightness Test. The dynamic tightness test is an alternative to the pressure-drop test. For shipyard use, if authorized by the Type Commander, the dynamic tightness test requires charging the system to its nominal operating pressure and maintaining a flow of compressed air into the system equal to the permissible leakage specified in the acceptance criteria in Table 551-1-5. If the system pressure remains constant or increases, then the system leakage meets the acceptance criteria. If the pressure decreases, then system leakage exceeds the metered inflow and is unacceptable.

Table 551-1-5 LEAKAGE RATE CRITERIA

Nominal System Operating Pressure	Allowable Leakage Percent of Total Installed Compressor Capacity
Low-Pressure Air System, below 151 lb/in^2 g	3.0
Medium-Pressure Air System, 151 - 1,000 lb/in^2 g	2.0
High-Pressure Air System, over 1,000 lb/in^2 g	1.5

551-1.16.1.3.1 The compact assembly of test instruments used in the dynamic tightness test includes gauges, valves, regulator valve, flowmeter, and connecting tubing. (This test equipment allows flow measurement with an accuracy of 1.5 percent and pressure measurement with an accuracy of 0.25 percent of full scale, and a resolution of 1/4 lb/in^2 pressure, and 1/10 scfm flow rate.)

551-1.16.1.3.2 Approved test instruments are the Leak-O-Lizer, Sterer dwg 53490, Sterer Engineering and Manufacturing Company, Los Angeles, CA and the DET-1 Leak Detector from Marotta Scientific Controls, Inc., Boonton, NJ. Technical manuals accompanying the test instruments provide instructions for their use.

551-1.16.1.3.3 Use the following recommended compressed air systems dynamics tightness test procedure.

1. Prerequisites. Before testing a component, assembly, or system:
   - a Perform an installation check to assure that the test subject is completely and correctly assembled according to the applicable drawings and is ready for testing in all respects. As a minimum, check for:
     - (1) Missing piping, components, and instrumentation
     - (2) Insufficient or improper pipe supports
     - (3) Components incorrectly installed.
   - b Complete system cleaning (flush) according to paragraph 551-1.16.3 and hydrostatic pressure testing according to paragraph 551-1.16.1.1 before performing tightness testing, observing all applicable test requirements and safety precautions presented in **NSTM Chapter 505, Piping Systems** .
   - c Calibrate flowmeter and gauges to meet the requirements of applicable test instrument technical manuals. The period between calibrations shall not exceed 6 months.
   - d Remove internal components of all check valves in the main influent airflow path (headers), regardless of direction of flow. Experience has shown that some check valve springs require differential pressure to open and initiate flow. Large volumes downstream of such check valves can then hide significant leakage. Tag check valves to ensure that internal components are replaced after leakage test is completed.
   - e Groom system according to shipyard pipefitting practices before conducting final system tightness test. A soap solution may be used to check the tightness of mechanical joints during grooming. During grooming, the test instrument may also be used to measure leak rates and to isolate major leakage areas in various system sections.
   - f For nuclear submarine testing, comply with the requirements of NAVSEA 0905-LP-485-6010,Manual for Control of Testing and Ship Conditions.
2. Safety. Follow applicable shipyard safety instructions for operating and testing high-pressure air systems.

Comply with requirements of NAVSEA 0905-LP-485-6010 for nuclear submarine testing, and with requirements of paragraphs 551-1.13.1 and 551-1.13.2 for all ship testing.

3. Test Procedure. Accomplish the test according to the following procedure:
   a Align system to permit tightness testing of all parts to be tested. Tightly close vent valves, drain valves, hose valve, and operating valves for end-use services.
   b Verify that piping system flasks and receivers are charged to nominal operating pressure, plus or minus the operating range specified in the test instrument technical manual.

NOTE

On ships with 4,500 lb/in^2 air systems, test may be conducted at 4,000 lb/in^2 if maximum dockside air pressure is 4,500 lb/in^2 or lower. If testing is conducted at 4,000 lb/in^2 for a 4,500 lb/in^2 system, the leakage acceptance criteria shall be decreased by 10 percent because it is considered that the leakage rate is proportional to system pressure.

   c Install test instrument discharge to inlet connection, gauge line, and hose outlet. Use soap solution to verify no leakage between test instrument and ship system.
   d Connect dockside air supply to test instrument inlet. If air supply is not oil-free, provide an oil removal filter as specified in paragraphs 551-1.15 through 551-1.15.6 to ensure supply of oil-free air. Assure that relief valve protection is provided, if necessary, to protect against over-pressurizing the test instrument.

NOTE

If dockside air is not available, test instrument may be installed using ship compressor and receiver/flask as air supply, if no more than one receiver/flask is used as air source and if that receiver/flask has been previously soap-tested with no detectable leakage.

   e Check out test instrument for proper operation and self-leakage according to instrument technical manual.
   f Open the test instrument flow throttle valve as required to produce a system influent flow rate equal to the maximum allowed system leakage as determined according to Table 551-1-5.
   g Using test instrument technical manual, determine the temperature-corrected flowmeter reading corresponding to the maximum allowed system leakage rate. During test period, monitor the flowmeter and adjust throttle valve to maintain flow at required rate.

NOTE

Experience has shown that two test personnel should be available during test: one person to adjust throttle valve and maintain flow rate, the other to observe time and outlet pressure and record readings.

   h Record initial system pressure [or Differential Pressure (DP) if test equipment is DP reference volume type]. Set red deadman's hand precisely above the black gauge hand. Record the following data: TIME 0 MIN 5 MIN 10 MIN 15 MIN
   Flowmeter
   Reading
   System
   Pressure
   i Observe the test instrument system pressure gauge (or DP gauge) for signs of pressure trend. If system

pressure increases or remains constant during the test duration, the leakage rate is acceptable. If system pressure decreases, then the system leakage exceeds the influent flow and leakage is unacceptable. Test duration shall be a minimum of 15 minutes. If leakage is unacceptable:

(1) isolate various portions of the system and use the test instrument to determine major leakage source. Correct major leaks.

(2) Repeat test procedure and adjust for leakage until test results are satisfactory.

NOTE

Single systems or groups of shipboard compressed air systems may be tested. If a single system (such as an aircraft carrier HP air system) is tested alone, all pressure-reducing station cross-connects shall be shut. However, on an SSN, the high-pressure air, service air, and emergency breathing systems shall be tested together, because the ship HP air compressors normally supply all three systems by way of reducing stations. If both HP air and service air systems on a ship are to be tested together (each system having its own compressor and allowed leakage rate), testing may be accomplished by opening the HP to LP pressure-reducing station cross-connects and conducting the test with the allowed maximum influent flow set at the maximum combined leakage rates for the HP and LP systems. If test is satisfactory, the cross-connects are then closed, influent flow set at only the HP air system valve, and the test is repeated. If both tests are successful, both system leak rates are satisfactory.

j After successful system testing, depressurize and remove test instrument and restore system to its normal configuration. Soap-test the system joint where test instrument was removed. There shall be no leaks.

k Reinstall removed check valve internal components. Soap-test all disturbed and depressurized joints. There shall be no leaks.

1. Acceptance Criteria. Use the following acceptance criteria or criteria otherwise specified in the applicable specifications or work package.

a Total system check or overhaul of new or good-as-new system.

b Partial system repair or overhaul. Use Table 551-1-5 leakage rate criteria by adjusting the permissible leakage rate downward to reflect the proportion of the total system being tested. Consult with appropriate design activities to estimate this proportion. If available time or conditions do not permit consultation, consider this proportion to be the same as the ratio of the sum of the total number of valves and mechanical joints being tested to the total number of valves and joints in the entire system.

c To avoid compressor cycling, obtain technical assistance in determining acceptable leakage for systems having relatively low, internal storage volumes and large compressor capacity. Whenever a major system overhaul has been completed, test the entire system as previously described.

551-1.16.1.4 PMS Drop Test and Groom Procedures. For ship classes where drop test and groom procedures have been incorporated into the PMS, the PMS procedure shall be followed.

551-1.16.2 INSPECTION (IN-SERVICE SHIPS). Compressed air systems for in-service ships shall be inspected for hydrocarbons and the other contaminants at overhaul periods or whenever contamination is suspected. Inspection shall be accomplished by collecting and examining the blowdown (condensate) from all flasks, receivers, separators, low-point drains, and disassembly of selected piping sections and components downstream of the compressor discharge. Blowdown (condensate) is collected by cracking the drain valves and blowing down according to paragraph 551-1.12.1.2.1 into a container until air begins to escape. Allow each sample of blowdown to settle and then examine visually under bright, white light for oil or particulate contamination.

551-1.16.2.1 Selection. Selection of representative piping sections and components for disassembly and inspection is important. If low points and drain pockets in the piping are free from contamination, it may be assumed that the piping system downstream of the uncontaminated, inspection point is also not contaminated, unless this piping has another supply source.

551-1.16.2.2 Contaminated Piping. When inspection of the piping sections and components selected for disassembly indicates the presence of oil contamination the maximum allowable contamination content of the cleaning compound sample after system flush should not exceed 50 parts per million (ppm) when cleaned in accordance with MIL-STD-1622. This does not include the compressor, or the piping between the compressor discharge and the discharge from the oil removal device. If inspection indicates that any major portion of the system inspected does not require cleaning, this section shall be isolated and not cleaned. Omission of unnecessary cleaning is particularly applicable to outboard flasks and where flasks do not have openings at both ends that would allow a continuous flow of the cleaning medium.

551-1.16.3 CLEANING (IN-SERVICE SHIPS). Compressed air systems shall be cleaned as follows:

1. For systems fed by oil lubricated air compressors or where inspection shows the presence of hydrocarbons, clean in accordance with MIL-STD-1622 until cleanliness and dryness requirements ofMIL-STD-1622 are met.
2. For systems fed by oil free air compressors, clean by blowing down in accordance with MIL-STD-1622 until cleanliness and dryness requirements of MIL-STD-1622 are met. When the system cannot be sufficiently cleaned by blowing down, a hot water flush in accordance with MIL-STD-1622 shall be done until cleanliness and dryness requirements are met.
3. For systems where brazing has been done, clean by hot water flush and cold water soak in accordance with MIL-STD-1622 until cleanliness and dryness requirements are met.
4. For systems where welding has been done, clean by blowing down in accordance with MIL-STD-1622 until cleanliness and dryness requirements of MIL-STD-1622 are met. When the system cannot be sufficiently cleaned by blowing down, a hot water flush in accordance with MIL-STD-1622 shall be done until cleanliness and dryness requirements are met.

551-1.17 AIR COMPRESSORS

551-1.17.1 CLEANING PROCEDURE. The intercoolers, aftercoolers, moisture separators and collecting traps; the interconnecting air piping and fittings between air coolers and compressor stages; the blowdown valves and associated piping and fittings; the air temperature monitor sensing elements if directly in the air stream, pressure gauges, wells and fittings, cylinder air valves, unloader valves, and check valves, shall be cleaned according to MRC's when provided. This cleaning shall be sufficiently thorough to restore the internal surfaces to the as-new condition with respect to cleanliness. Components shall be removed from the compressor for cleaning. Disassembly, reassembly (using a new set of gaskets), and testing of compressor and components shall be accomplished according to instructions and safety precautions specified in applicable maintenance manuals.

551-1.17.1.1 The system air side of intercoolers, aftercoolers, interconnecting air piping, moisture separators, separator collecting traps, blowdown valves, blowdown piping, temperature sensing elements or temperature element wells, cylinder air valves, unloader valves, and check valves, with components disassembled as necessary, shall be soaked in a boiling solution of cleaning compound, FED Spec P-C-437, and fresh water mixed in the proportion of 1 gallon of water to 4 ounces of compound. Protective gloves shall be worn when using this compound.

551-1.17.1.2 The soaking period shall be 1/2 hour followed by scrubbing with suitable brushes (metallic bristle brushes should not be used on critical seating surfaces). This soaking and scrubbing process shall be repeated until the parts are clean. After soaking and scrubbing, the parts shall be adequately rinsed in fresh water and thoroughly dried with clean air. Cleaning compound, FED Spec P-C-437, is procurable through the Navy Supply System as follows:

NSN Container Size

6850-00-664-7056 25 lb drum

6850-00-256-0157 125 lb drum

6850-00-256-0158 400 lb drum

551-1.17.1.3 The cooling water side of intercoolers and aftercoolers shall be cleaned by brushing accessible surfaces with a stiff bristle brush and cleaning out loose deposits with an air, steam, or water-jet. Inaccessible surfaces and surfaces covered with scale which cannot be removed by the preceding procedure shall be acid cleaned as specified in NSTM Chapter 531 Volume 1, Desalination Low-Pressure Distilling Plants.

551-1.17.1.4 Temperature sensing elements shall be cleaned by the method prescribed in paragraph 551-1.17.1.1, except that special care is required to prevent injury to the electrical conductor of the element (where used) and the thin metallic element cover.

551-1.17.1.5 Small components may be cleaned in an ultrasonic cleaner if experience shows this method to be effective. Use a detergent cleaning solution or other cleaning solvent compatible with the environment as recommended in the ultrasonic cleaner manual.

551-1.17.1.6 Pressure gauges shall be cleaned and calibrated according to the applicable procedures in NAVSEA OD 45845.

551-1.17.2 COMPLEX CLEANING PRECAUTIONS. Chemicals prescribed in the preceding paragraphs, except those used in connection with ultrasonic cleaning, shall not be stored onboard submarines nor used in a closed submarine hull. Precautions required for using the acid cleaning method specified in paragraph 551-1.17.1.3 are appropriately covered in **NSTM Chapter 531 Volume 1** . In the event it becomes necessary or desirable to perform the cleaning operation described in paragraph 551-1.17.1.1 in a closed submarine hull and to store the cleaning compound onboard, refer to the PMS and the applicable technical manuals.

551-1.17.3 LUBRICATION PRECAUTIONS. There is evidence that oils prescribed in paragraph 551-1.17.4 will attack materials containing lead. Although this is not a problem with Ingersoll-Rand compressors installed on submarines, it is not recommended that these oils be used in compressors of other manufacturers where such a problem may exist. The use of the oils prescribed in paragraph 551-1.17.4 on other than Ingersoll-Rand high-pressure submarine compressors shall not be attempted without specific approval by NAVSEA.

551-1.17.4 LUBRICATION REQUIREMENTS. All HP air compressors manufactured by Ingersoll-Rand Company and installed on submarines shall be lubricated with the following lubricating oils:

a. Crank Case (bearing) Lubrication. Lubricating oil, 2190 TEP or MIL-L-26087 grade I, and having a viscosity of 8-11 centistokes at 98.5° C (210° F). These oils are procurable from the Navy Fuel Supply Office under the following National Stock Numbers:

   NSN SIZE

   9150-00-577-4241 1 gallon

   9150-00-682-6771 5 gallon

b. Cylinder Lubrication (except oil-free air compressors). Lubricating oil, MIL-L-26087, except that it shall have a minimum viscosity of 16 centistokes at 98.5° C (210° F). This oil is procurable from the Navy Fuel Supply Office under the following National Stock Numbers:

   NSN SIZE

   9150-00-965-2399 1 gallon

   9150-00-965-2400 5 gallon

   9150-00-753-4636 55 gallon

551-1.17.4.1 Before charging the crankcase sump and cylinder lubricator reservoirs with the foregoing oils, make certain that the reservoirs have been thoroughly drained and cleaned according to applicable maintenance manuals. The Madison Kipp (model SV or SVH) lubricator sight flow indicators shall be filled only with glycerine, not mixtures of glycerine and water, as is the case with some other oils.

SECTION 2.

SURFACE SHIPS

551-2.1 INTRODUCTION

551-2.1.1 Compressed air plants and systems provide compressed air at the required pressures, flow rates, quality, and cleanliness required by the ship's equipment and services. The success of the surface ship's mission depends upon the capability of the compressed air systems to satisfactorily support these services. Air plants and systems are categorized by their operating pressures and services as follows:

a. High-Pressure (HP) Air Plants and Systems

b. Medium-Pressure (MP) Air Plants and Systems

c. Low-Pressure (LP) Air Plants and Systems

d. Independent Special Air Plants and Systems.

551-2.1.2 The selection and configuration of any one or combination of the above air system categories depends upon the following combination of factors: ship type, mission and arrangement, type of propulsion plant and controls, type of electric generator plant (main and emergency), weaponry, electronic suite, normal and special ship services, and functions requiring specific air demands (pressure, flowrate, quality, cleanliness). This section discusses and describes the various configurations of compressed air plants and systems selected and installed to best support the compressed air demands of a given type of surface ship.

551-2.2 HP AIR PLANTS AND SYSTEMS

551-2.2.1 GENERAL. HP air plants and systems are generally designed to provide compressed air at a nominal operating pressure of 3,000 lb/in^2 or 5,000 lb/in^2 . HP air plants and systems shall be installed whenever one of the ship's services requires a pressure in excess of 1,000 lb/in^2 , or whenever a ship function requires a flow rate of compressed air that cannot be readily supported by either a LP or MP compressed air plant installation. HP compressed air plants support functions which require high flow rates of compressed air by the addition of HP air storage flasks to the system. Once an adequate quantity of compressed air is stored in these HP air flasks, the high flow rates and pressure demands can be supported by way of air pressure reducing stations. Generally, 3,000 lb/in^2 (place of 5,000 lb/in^2) compressed air plants and systems are provided unless the following conditions prevail:

a. Services require air pressures in excess of 3,000 lb/in^2

b. Space is at a premium and substantial space can be saved by the storage of compressed air at the higher 5,000 lb/in^2 pressure.

551-2.2.2 AIR PLANTS AND SYSTEMS. An HP compressed air plant and system consists of:

a. A compressor (MIL-C-23961 for aircraft carriers and tenders and MIL-C-18419 for submarines and other surface ships)

b. Accompanying instrumentation and controls

c. Relief valve

d. Moisture separator flask

e. Oil-particulate filter (generally omitted when oil-free compressors are installed)

f. Check valve

g. Dehydrator (with disposable cartridge-type bypass dehydrator)

h. Piping distribution system
   1 Mains
   2 Headers
   3 Branches
   4 Gauges
   5 Assorted valves
   6 Pressure controls which provide compressed air on demand.

551-2.2.2.1 The normal configuration, a minimum of two plants, is installed on combatant ships (one serving on standby, see Figure 551-2-1). When the air plants are located in separate compartments (preferred arrangement), the HP air main serves as the cross connection between the air plants. If more than one air plant is located in the same compartment, the plant storage flasks are grouped and discharge into a common header to the HP air main. Air plants are generally located in machinery spaces for convenience of attendance and control by the Engineering Department.

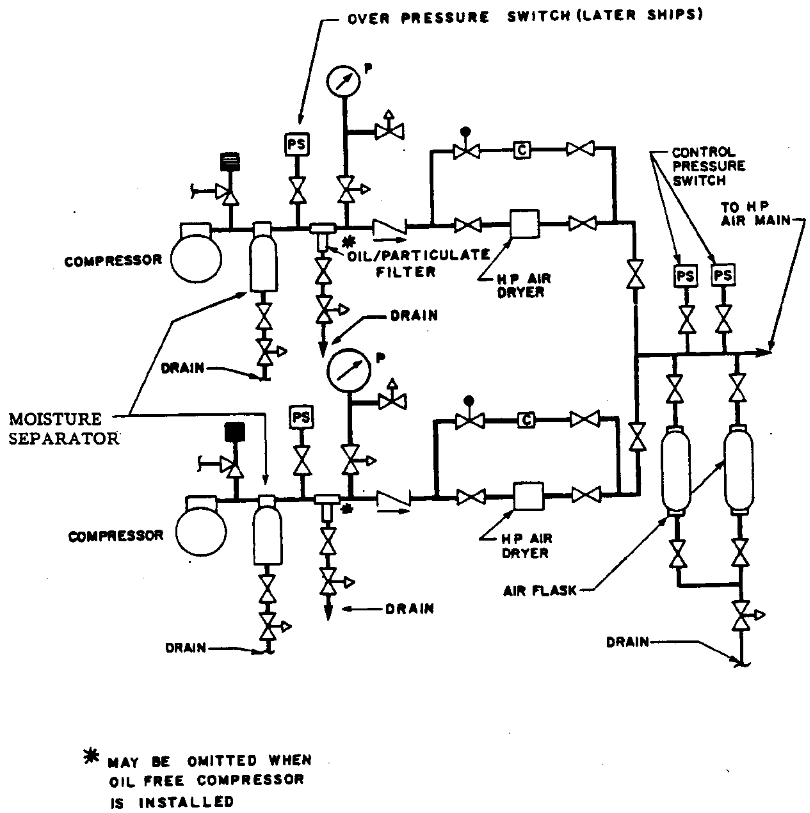


Figure 551-2-1 Typical HP Compressed Air Plant

551-2.2.2.2 The HP air compressor may be operated in the automatic or manual mode. In the automatic mode, the compressor starts in response to the preset low cut-in pressure at the pressure switch located downstream of the plant storage flask. This switch setting is approximately 2,500 to 2,800 lb/in^2 cut-in pressure for 3,000 lb/in^2 compressors, and 4,200 to 4,700 lb/in^2 cut-in pressure for 5,000 lb/in^2 compressors. The compressor stops when system pressure at a second cutout pressure switch at the same location reaches 3,000 or 5,000 lb/in^2 as appropriate.

551-2.2.2.3 In the manual mode, pushing the start button permits the compressor to start if the system pressure is below the preset pressure level of the cutout pressure switch. As in the automatic mode, the compressor will stop when the system pressure at the cutout pressure switch reaches 3,000 or 5,000 lb/in^2 , but will not restart when the system pressure drops to the cut-in pressure. The compressor may be stopped or taken out of operation at any time by pressing the stop button.

551-2.2.2.4 HP air system status is remotely monitored in the Enclosed Operating Station (EOS), Damage Control Central (DCC), or Central Control Station (CCS), including an audible/visible fault alarm for each compressor. Compressor status monitoring is also provided locally at the compressor. Pressure gauges provided at the compressor indicate air delivery pressure from each stage of compression, the pressure in the condensate accumulator, the pressure in the circulating water system, and the lubricating oil system pressure. Temperature indication is provided at the inlet and outlet of each stage, on final air discharge temperature, the lube oil temperature in the reservoir, the cylinder cooling water temperature, and the seawater outlet temperature.

551-2.2.2.5 Formerly, HP compressors were generally specified to operate unloaded with the selector switch in Automatic and the system pressure at the preset cutout point (3,000 or 5,000 lb/in^2). Unloaded operation continued for 10 minutes unless operation in fully loaded condition resumed due to system pressure dropping to the cut-in point. After 10 minutes of unloaded operation, the compressor would stop but would restart automatically if the system pressure dropped to the cut-in point. The **start-unload** operation in **Automatic** was specified because it was believed that it would reduce compressor wear. However, unloaded operation of the compressor proved to be a noisy mode.

551-2.2.2.6 When the change to oil-free HP air compressors was made, manufacturers found difficulty in designing for start-unload operation in Automatic.

551-2.2.2.6.1 Consequently, this type of control was abandoned in favor of start-stop operation in Automatic. Automatic compressor shutdown and alarms are provided in case of occurrence of the following faults:

a. Excessive air discharge temperature from any stage and from aftercooler

b. Low lube oil pressure

c. Condensate drain system malfunction

d. High cylinder cooling water outlet temperature.

551-2.2.2.7 Additional automatic compressor shutdown may be provided for high lube oil temperature, cooling seawater discharge temperature, and other faults at the discretion of the compressor manufacturer. For additional information on HP air compressors, refer to Section 4; for a description of the function of other HP air plant components such as the moisture separator, oil-particulate filter, air dehydrator, and air flasks, refer to Section 1.

551-2.2.3 AIR MAIN. HP air distribution systems are configured to minimize the extent of piping and number of components while providing maximum reliability and flexibility in the supply to all services. In general, the HP air main configuration may be a vertical loop, horizontal loop, or a single main. The selection of an HP air main configuration depends on the type and mission of a particular surface ship.

551-2.2.3.1 For high tonnage ships, such as aircraft carriers, amphibious assault ships, or battleships, the HP air main consists of a vertical loop. The lower portion of the loop runs through the machinery spaces to include services low in the ship and the compressed air plants supplying the system. The upper portion of the loop runs beneath the flight deck with extensions forward and aft as necessary, supplying the required services higher in the ship. The upper and lower portions of the loop are connected by risers, one located in the forward-most machinery room, and one located in the after-most machinery room. A third riser may be provided from machinery spaces (see Figure 551-2-2).

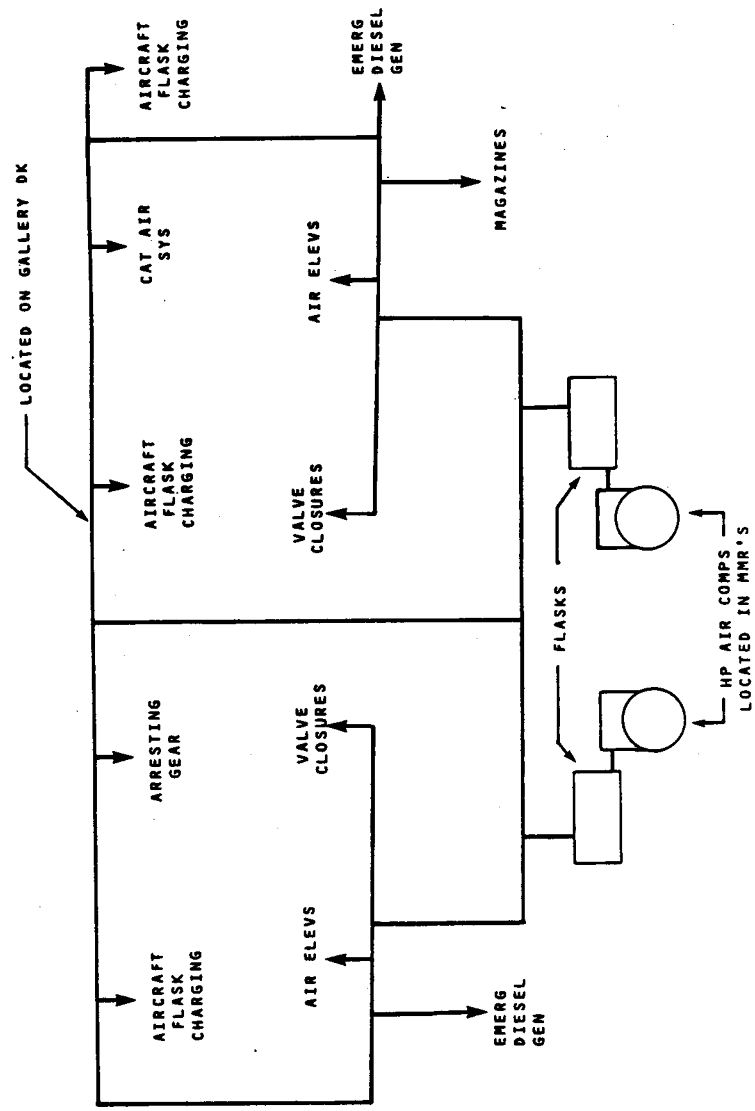


Figure 551-2-2 Typical HP Air Main Configuration (Vertical Loop on Aircraft Carrier)

551-2.2.3.2 For other ships with wide beams and numerous services, such as tenders, the HP air main consists of a horizontal loop with two mains, one port and one starboard, running beneath the main deck and extending fore and aft as necessary in supplying the required services. The port and starboard mains of the loop are cross-connected at the forward and aft extensions of the mains. For combatant and auxiliary ships, the HP air main consists of a single main which runs through the machinery spaces where it is connected to the compressor plants and then extends forward and aft at one or more deck levels depending on where the services to be supplied are located (see Figure 551-2-3).

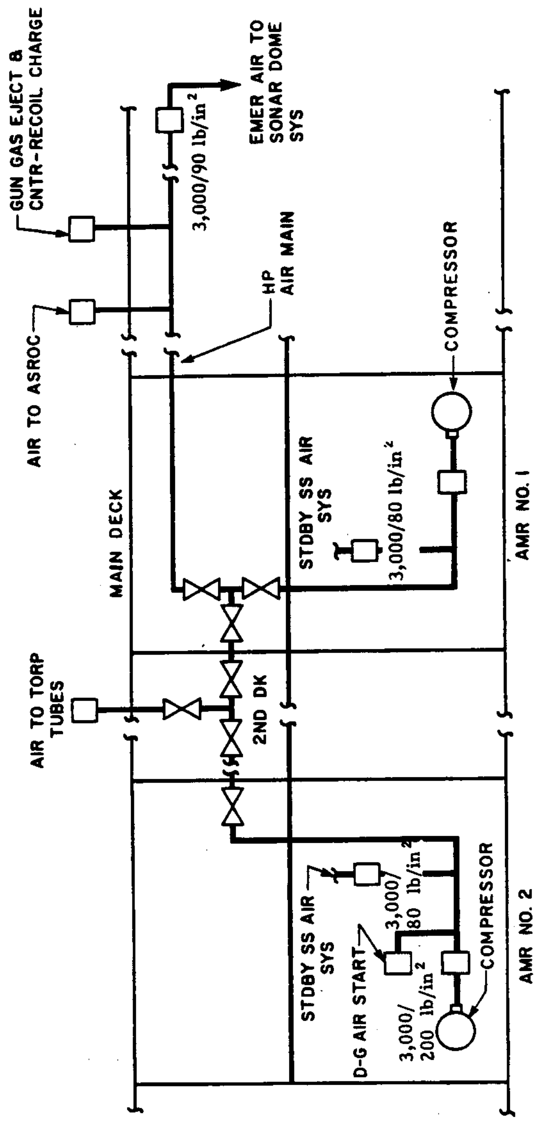


Figure 551-2-3 Typical HP Air Main Configuration (Single Air Main on FF-1052 Class)

551-2.2.4 AIR SERVICES. The following paragraphs discuss various services using HP air.

551-2.2.4.1 General. HP air services are supplied by branches from the HP main to the service locations. Where it is essential to ensure availability of an adequate air supply at required pressure regardless of other simultaneous demands, dedicated air banks are provided. Such a service branch line installation is provided with a cutout valve and a check valve upstream of the air bank to prevent flow from bank to main, and an additional cutout valve. A bypass, with a normally closed valve, is installed around the first cutout valve and check valve to permit airflow from this air bank, when circumstances require, back to the air main. Where dedicated air banks are not provided, such as the branch piping for the cross connection to the ship service air system, the air flask discharging to the air main is considered adequate. Some services are directly connected to the HP air main and are supplied through pressure-reducing manifolds (see Figure 551-2-4 and Figure 551-2-5).

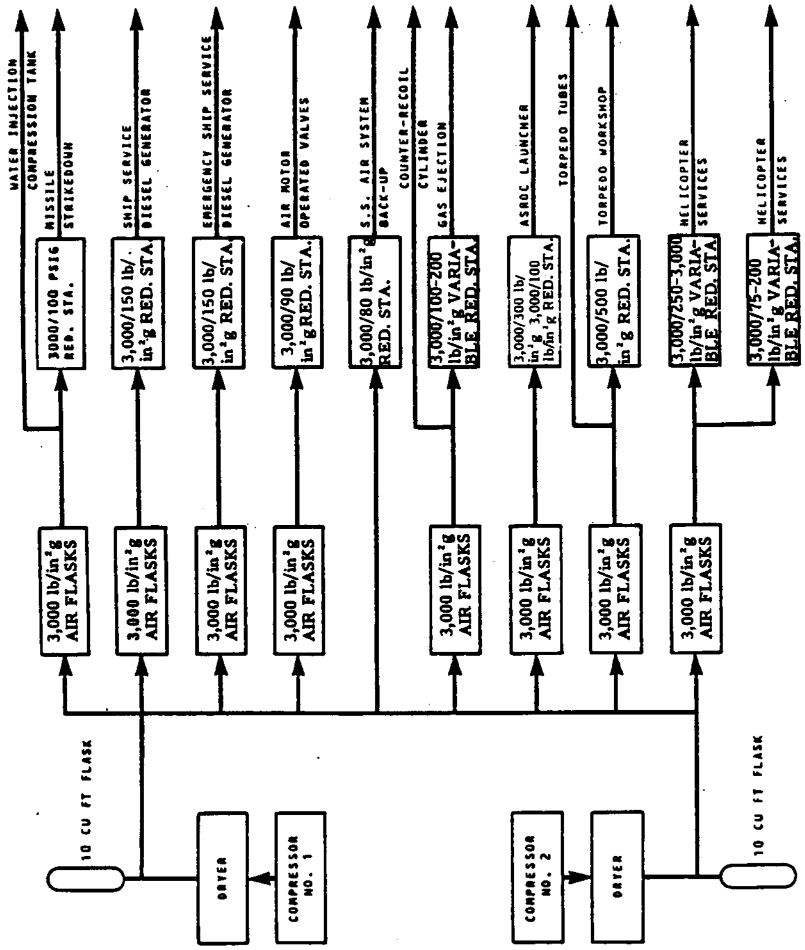


Figure 551-2-4 Typical HP Air Functional Diagram

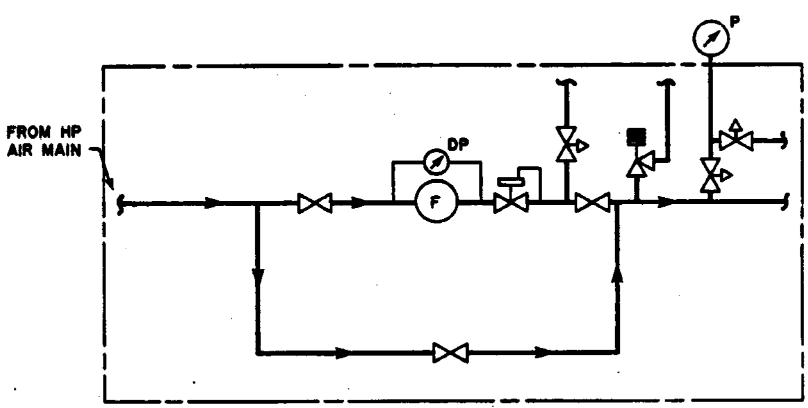


Figure 551-2-5 Typical HP Air Pressure Reducing Manifold

551-2.2.4.2 Weapon Support. The HP compressed air system supplies air at required pressures and flow rates for the following services:

a. Air for Torpedoes. Weapons are propelled from the torpedo tubes with a blast of HP compressed air. This HP air is provided from the torpedo tube breech mechanisms (flasks) which are charged from the HP air main by way of a branch-off provided with a stop valve, a check valve, and a normally locked-closed bypass valve. Each charging station consists of an air bank, a stop valve, a 50-micrometer nominal size filter, a throttling valve, a valved bleed connection, a pressure gauge, a relief valve, and a threaded charging connection suitable for use with the hose furnished with the torpedo tube (see Figure 551-2-6). The torpedo workshops are provided with HP compressed air for servicing the torpedoes as follows downstream of the air bank: a 3,000 lb/in^2 outlet by way of a stop valve, cartridge-type oil filter, throttling valve, gauge, and bleeder-type stop valve; and a 500 lb/in^2 test outlet by way of a 3,000/500 lb/in^2 pressure reducing manifold (see Figure 551-2-7).

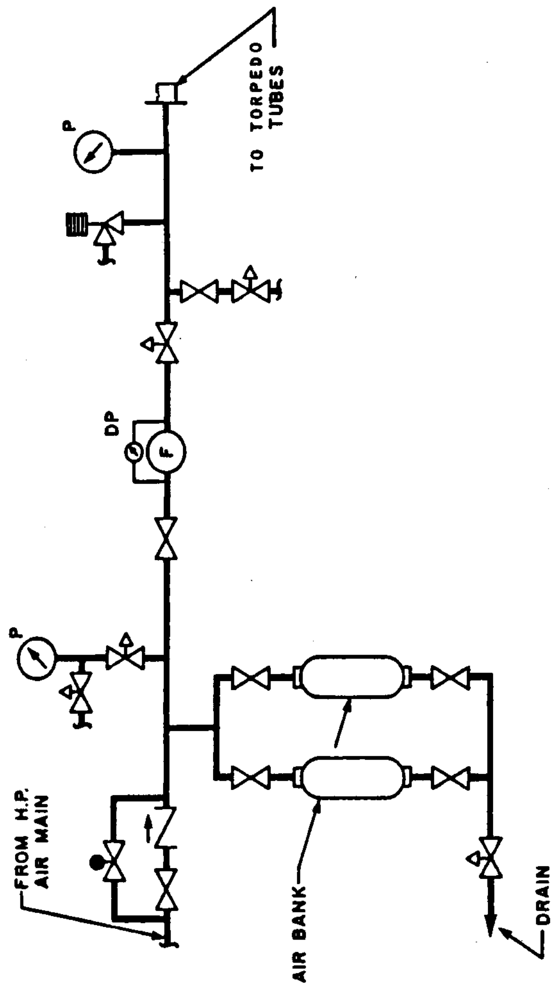


Figure 551-2-6 Typical Piping to Torpedo Tubes

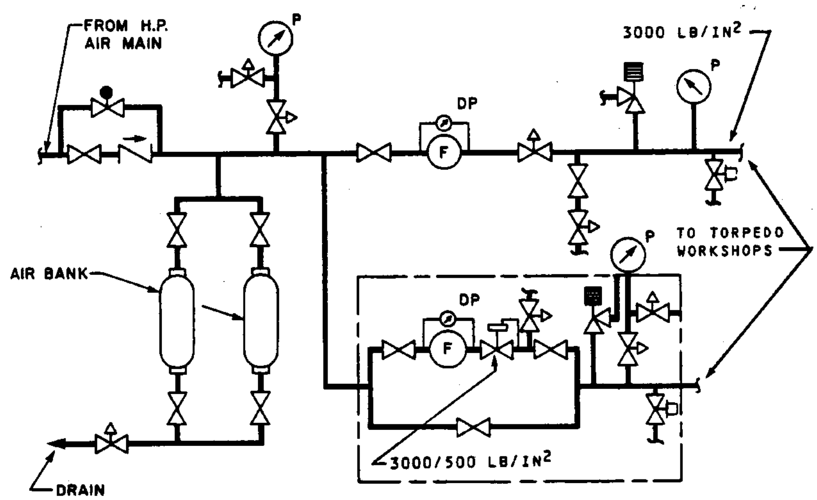


Figure 551-2-7 Typical Piping to Torpedo Workshops

b. Air for Guided Missile Launching System (GMLS) Magazine Missile Water Injection. A branch line from the HP air system is provided for charging the GMLS magazine water injection compression tank (see Figure 551-2-8).

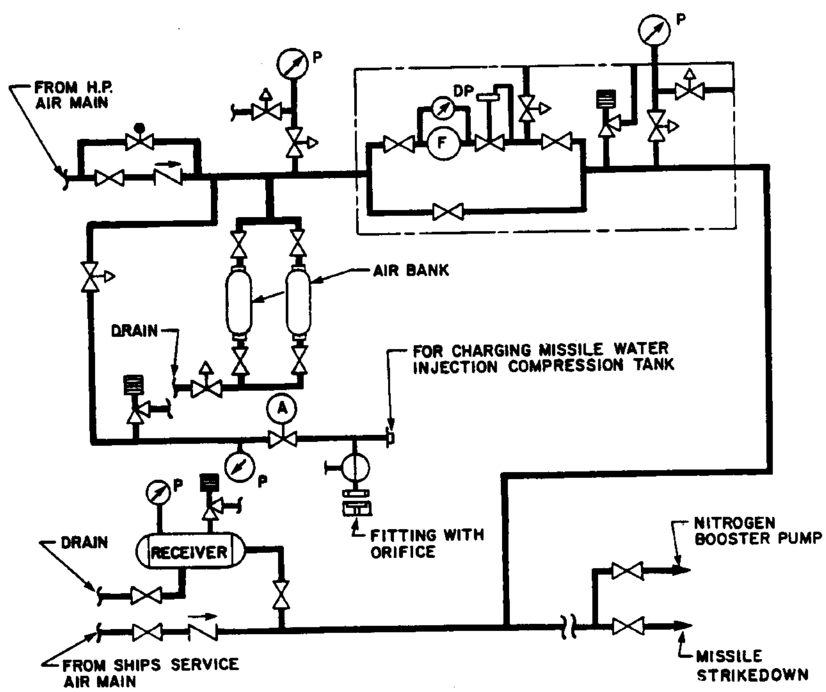


Figure 551-2-8 Typical Piping for Missile Service

c. GMLS Missile Strikedown. Missile strikedown aboard surface ships is performed by davits and hoists powered by air-operated motors. HP air stored in air flask is delivered to the air motors by way of a 3,000/100 lb/in^2 pressure reducing manifold (see Figure 551-2-8).

d. Gas Ejection and Counter-Recoil Systems. The HP air system provides air by way of an air bank and reducing station to the gun mounts. This air is used to evacuate gases and unburned solid matter from the bore after firing, and for emergency or maintenance operation of the gun barrel train and elevation systems. The standard nominal operating pressure of this system is determined by the type of battery, ranging from 100 to 200 lb/in^2 . Air is stored for this system in an air bank sized to provide the required capacity of replenishment air necessary for firing all allotted ammunition (see Figure 551-2-9). The capacity of the relay tank is dependent upon the size of the gun. The gas-ejecting air supply is run from the relay tank(s) through the central column pedestal of the gun mount. The air supply for emergency and maintenance operation of the train and elevation systems is provided by a branch off the gas-ejecting air supply and reduced at required pressures. An outlet for emergency supply to charge counter-recoil cylinders is upstream of the air bank.

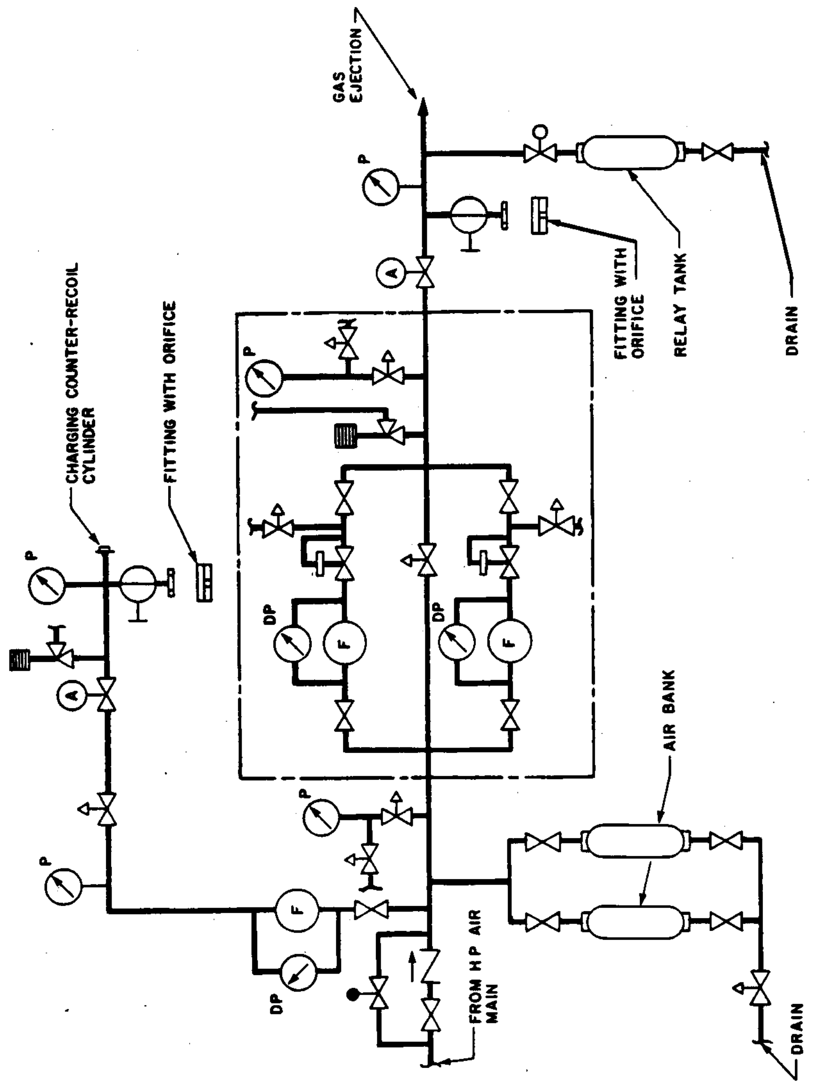


Figure 551-2-9 HP Air for Gas Ejection and Counter-Recoil

551-2.2.4.3 Aviation Support and Weapons Handling. The HP compressed air system also supplies air at required pressures and flow rates for the following services:

a. Charging catapult hydraulic system, by way of air supplied at 3,000 lb/in^2 to each catapult air charging panel.

b. Emergency air supply to each catapult air charging panel, by way of air flasks and a 3,000/125 lb/in^2 reducing manifold. Flasks are sized to support approximately 60 launches.

c. Emergency air supply to catapult steam accumulator air control system, by way of a 4-ft3 lask and 3,000 lb/in^2 reducing manifold.

d. Charging control panels for arresting gear and barricade engines and arresting gear auxiliary air flasks, air supply at 3,000 lb/in^2 .

e. Damper sheave charging panels, air supply at 3,000 lb/in^2 .

f. Barricade stanchion control panel, air supply by way of a 3,000/1,500 lb/in^2 reducing manifold.

g. Automatic lubrication system for arresting gear engines, air supply by way of air flasks, and a 3,000/125 lb/in^2 reducing manifold. The flasks have sufficient capacity for recovery of approximately 60 aircraft.

h. Aircraft elevator hydraulic accumulator pressure flasks, air supply at 3,000 lb/in^2 for charging.

i. Hydraulic plants for upper and lower weapons elevators, air supply at 3,000 lb/in^2 for charging.

j. Catapult services, including air supply to bridle control valve, arresting console, and accumulator. For reference to various aviation support services listed above, see Figure 551-2-10 and Figure 551-2-11.

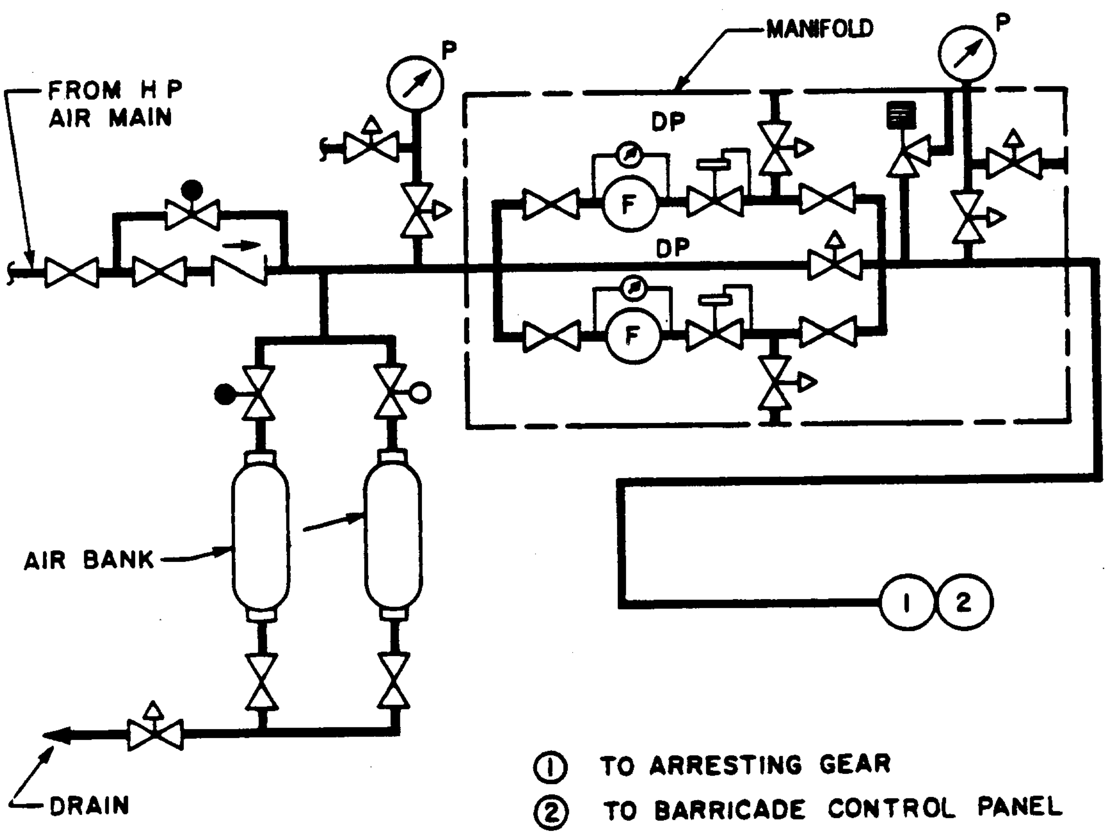


Figure 551-2-10 Aviation Support - Typical Piping Arrangement

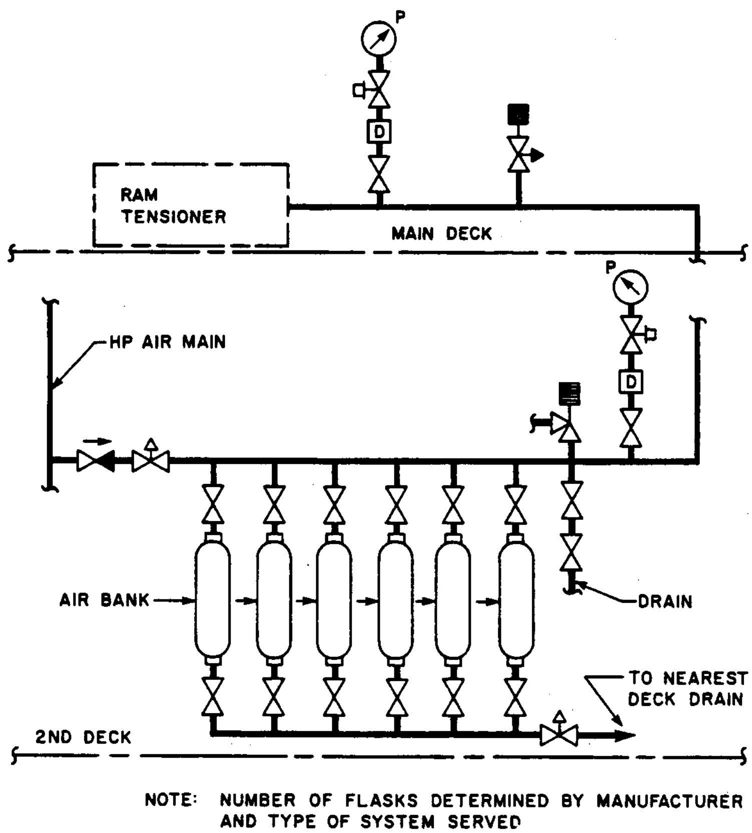


Figure 551-2-11 Typical Piping Arrangement to RAM Tensioner

551-2.2.4.4 Engine Starting Air. Starting air for diesel engines and gas turbines is supplied by a branch line from the HP air system or by dedicated air compressors. In either case, the air is stored in starting air flasks at high-pressure and then provided to an engine by way of a pressure reducing manifold. It is noted that the air piping from the starting air flasks to an engine has added flexibility provided because of the intense vibration of a starting engine.

551-2.2.4.5 Diesel Engine Starting. A compressed air starting system is installed on all ships that require air for diesel engine starting. Each diesel engine is provided an air bank and a pressure reducing manifold set at the required starting pressure. Each air bank has a minimum capacity for one cold start and nine hot starts without recharging, and is normally located within the same compartment as the engine it serves. A locked-open valve is provided at each flask discharge. A pressure reducing manifold is installed downstream of the air bank for each diesel engine.

551-2.2.4.5.1 An additional backup air bank, to provide at least 10 starts, is installed for each compartment which contains 1 or more diesel engines. The discharge from the backup air bank is connected to each starting air supply main upstream of the pressure reducing manifold. The backup air flasks are isolated from each starting air supply main by a normally closed cutout valve. The discharge from the pressure reducing station is provided with a control valve and two starting valves (a manual and an automatic) installed in parallel. The automatic starting air valve is actuated by one or more solenoid valves as necessary (see Figure 551-2-12).

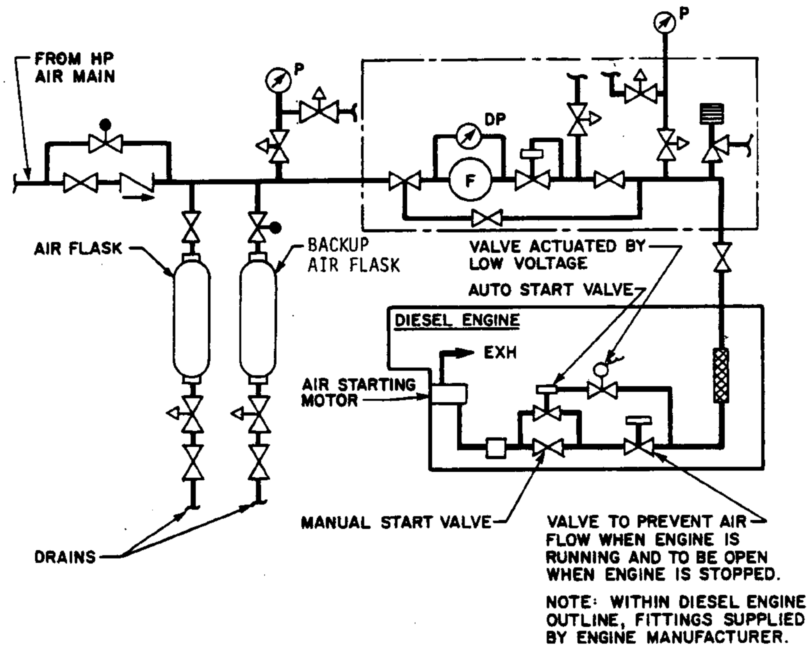


Figure 551-2-12 Typical Diesel Engine Starting Air

551-2.2.4.6 Gas-Turbine Starting. One starting air bank is provided in each compartment which contains one or more gas-turbine engines. The air bank has a capacity to provide a minimum of three engine starts for each engine served without the need for recharging. A locked-open valve is provided at each flask discharge. A pressure reducing manifold is installed downstream of the air flasks and is set at the starting air pressure required for the engine or engines in that compartment. Subsequent starting of additional engines may be provided by a bleed air system. Where bleed air from another gas-turbine in operation is provided, a check valve and pressure gauge is installed downstream of the pressure reducing manifold. The bleed air supply line is connected to the compressed air starting system downstream of this check valve and pressure gauge and is provided with a check valve and isolation valve at its connection to the compressed air starting system.

551-2.2.4.6.1 The starting air supply piping downstream of the pressure reducing manifold is provided with a cutout valve and control valve. For ships having two or more gas-turbines that are started by way of a common pressure reducing manifold, the starting air supply piping downstream of the pressure reducing manifold branches into separate lines for each engine served. Each air supply line is provided with a cutout valve and control valve (see Figure 551-2-13).

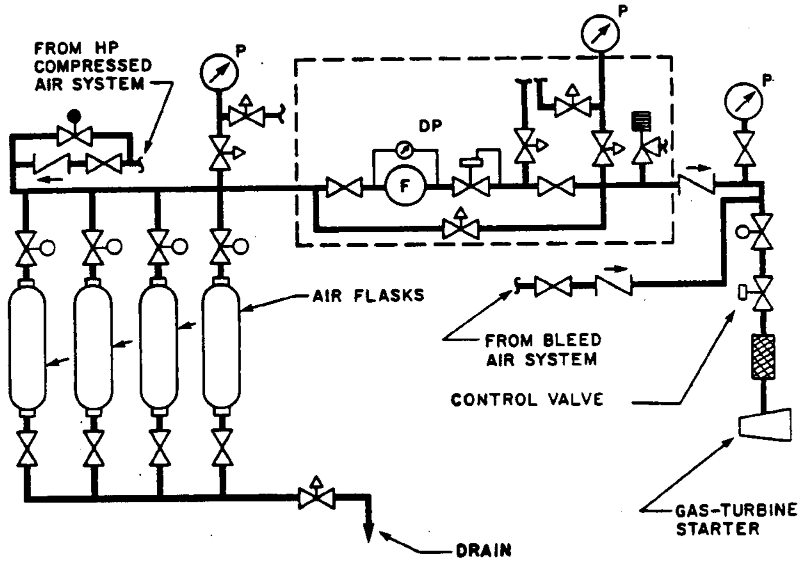


Figure 551-2-13 Typical Gas-Turbine Starting Air

551-2.2.4.7 Ship Service Air System Backup. The HP air system provides backup air by way of a 3,000/80 lb/in^2 pressure reducing station cross connection to the ship service air system.

551-2.2.4.8 Air for Emergency Lube Oil Pumps (Coast-Down). The HP air system charges a 3,000 lb/in^2 g air flask to provide sufficient air for one complete lube oil pump coast-down operation without recharging. Air is delivered to the air motors at the required flow by way of a 3,000/90 lb/in^2 pressure reducing manifold. A pulsation dampener, a solenoid operated valve which opens with falling lube oil pressure or the loss of electrical power, and a pressure switch set to actuate a remote pump running indicator light are installed downstream of the pressure reducing manifold.

551-2.2.4.9 Emergency Pneumatic System for Air Motor-Operated Valves. An air flask charged from the HP air system is provided to supply air (sized with sufficient volume to fully close each valve it supplies) by way of a reducing station to valve air motors for emergency closure of pneumatically operated machinery plant valves when the ship service air system is inoperative or inadequate (see Figure 551-2-14).

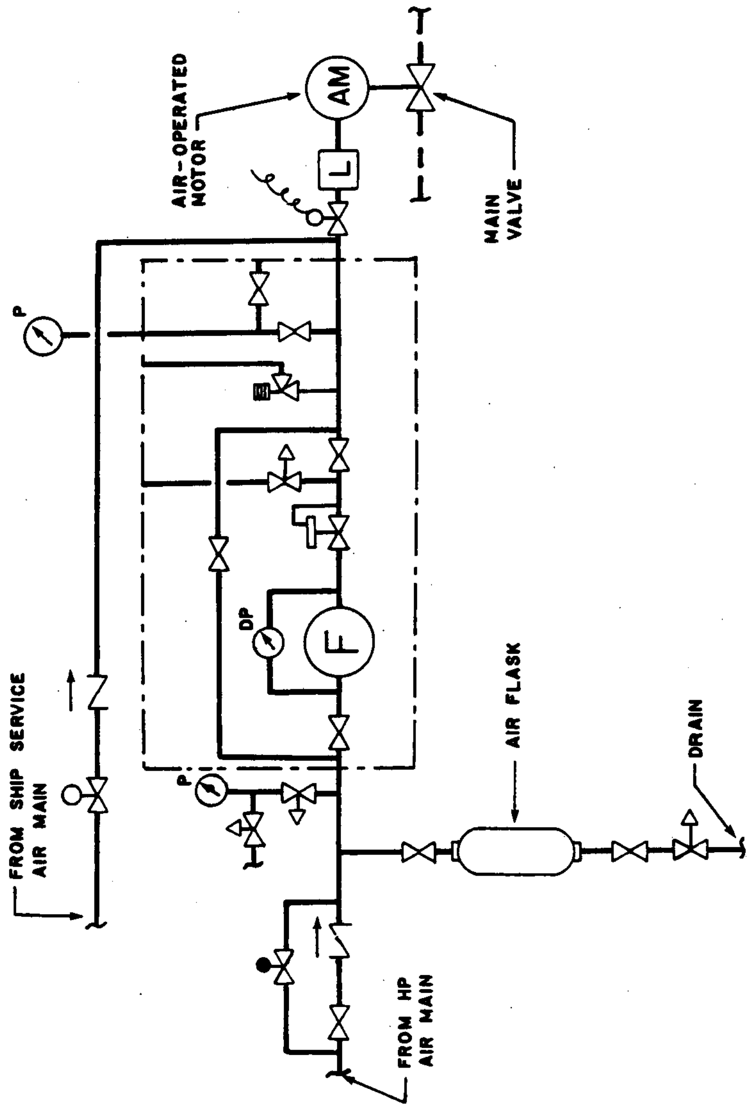


Figure 551-2-14 Typical Piping for Air Motor-Operated Valves

551-2.2.4.10 Antisubmarine Rocket (ASROC) Launcher Air Service. An air bank and pressure reducing manifold is installed in the HP air system to provide air at required pressure for snubbers and guide rail extension system at ASROC launcher (see Figure 551-2-15).

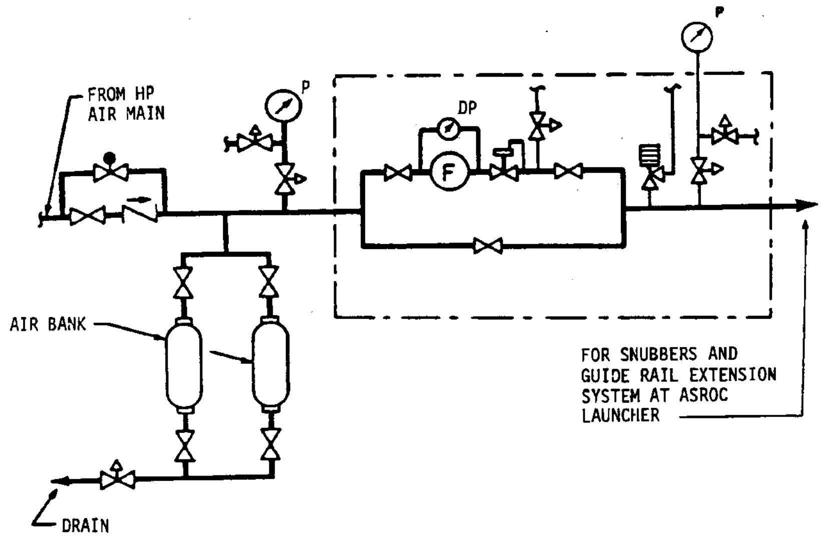


Figure 551-2-15 Typical Piping for ASROC Launcher

551-2.2.4.11 Emergency Air Breathing. Air is supplied to the Emergency Air Breathing (EAB) system from the HP air system and from the LP air system by way of the vital service air system. The EAB system terminates at EAB stations. When the HP air supplies the EAB system, a globe valve, lift check valve, another globe valve, air flasks, pressure gauge, pressure reducing station, and EAB stations are installed, in that order. The valve downstream of the lift check valve is normally closed and readily accessible. Flasks are sized to provide a minimum of 1 standard cubic foot of air per minute (scfm) at each connected EAB station outlet for a period of at least 4 hours of service. Flasks and pressure reducing stations are located in the same spaces as the associated EAB stations (see Figure 551-2-16).

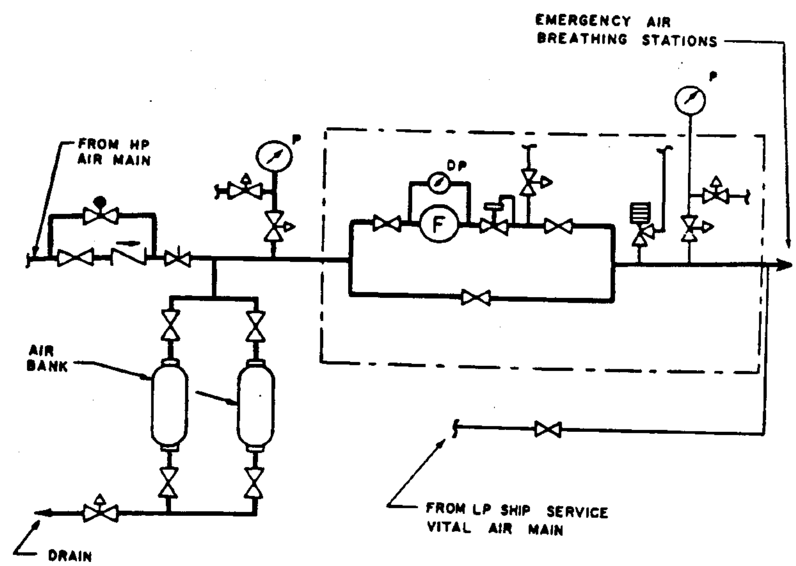


Figure 551-2-16 Emergency Air Breathing Service Arrangement

551-2.2.4.12 Air for Helicopter Services. For ships that require compressed air in place of nitrogen for helicopter air services, air is provided from the HP air system. The installation consists of five air flasks; three stowed in the compressed gas storeroom to serve as spares reserved for helicopter service, and two of them in the hangar to supply the helicopter service header. Two parallel branches each supply two service outlets. One branch supplies two HP outlets and the other branch supplies two LP outlets. Two outlets (one HP and one LP) are located in the hangar and two outlets (one HP and one LP) are located in a watertight deckbox in the landing area. Each of the parallel branches consists of a pressure regulator, pressure relief valve, pressure gauge, automatic cutout valve, and a hose outlet valve. Hoses provided are suitable for HP branch (3,000 lb/in^2 service) and for LP branch (1,800 lb/in^2 service). A key-operated plug cock is installed downstream of each automatic cutout valve for testing the valve (see Figure 551-2-17).

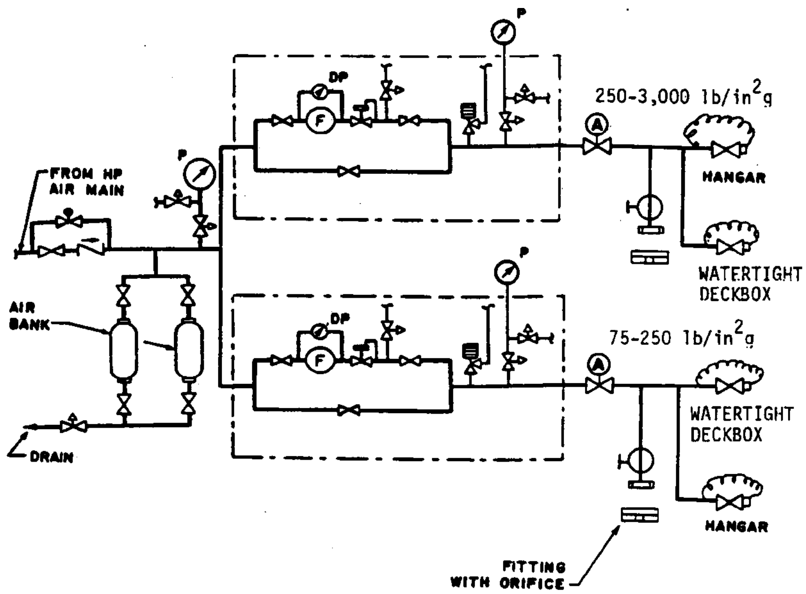


Figure 551-2-17 Air for Helicopter Services

551-2.2.4.13 Oxygen-Nitrogen (O_2 N_2) Producer Air System Supply. Air is normally supplied to each HP O_2 N_2 producer by way of an HP air compressor similar to the ship's HP air system HP air compressors (MIL-C-23961). An emergency air supply is provided to each HP O_2 N_2 producer from the ship's HP air system. In turn, the piping is arranged to allow the O_2 N_2 producer HP air compressor to serve as an emergency supply to the ship's HP air system.

551-2.3 MP AIR PLANTS AND SYSTEMS

551-2.3.1 GENERAL. The MP air system, by definition, is designed for a nominal operating pressure of 151 lb/in^2 to 1,000 lb/in^2 . These values of pressure are provided by either an MP air plant and system or an HP air plant and system supplying air at required pressures for services by way of an air bank and pressure reducing station. The selection, application, and configuration of any one of the foregoing air systems depends upon the function, type, and mission of a surface ship. MP air plants and systems are installed on ships such as minesweepers, PG and PGG types, LST's, ASR's, and tugs. Also, various arrangements have been provided in the past for supplying a separate MP air plant and system on certain older ships.

551-2.3.1.1 When both HP and MP air services are required for a given ship, the option of installing both an HP air plant and system and an MP air plant and system, or only an HP air plant and system, exists. Substantial gains in space can be affected by storing compressed air at HP (3,000 lb/in^2) for later use at MP. Therefore, an HP air plant and system can deliver HP air directly to services as required, and indirectly by way of an air bank and pressure reducing manifold for services which require a pressure within the MP range.

551-2.3.2 AIR PLANTS AND SYSTEMS. Navy standard oil-free compressors, filters, and dehydrators have not been developed in the MP range. The MP air compressors now in use have oil-lubricated cylinders and are generally rated at 10 scfm or 50 scfm at 600 lb/in^2 . An MP air plant and system generally consist of a motor-driven compressor, receiver, and an air main with branches to the various services. Automatic control is designed to stop the compressor when the receiver pressure reaches the upper pressure limit of the system, and to restart the compressor when the receiver pressure falls to the lower pressure limit of the system. Minesweeper and tug compressors are controlled locally in the machinery space. PG-type ships have local control, with remote control and monitoring at the CCS.

551-2.3.3 AIR MAIN. The MP air main consists of a single main which extends through the machinery spaces where it connects to the air plant discharge and then extends forward and aft at one or more deck levels as necessary to include all the services to be supplied.

551-2.3.4 AIR SERVICES. The following paragraphs describe the services requiring MP air.

551-2.3.4.1 General. Air is supplied from the MP air main and distributed to each service by way of a system of piping branches. Services requiring MP air are supplied directly through a branch from the air main. Services, such as engine starting requiring a sustained airflow rate greater than the rated capacity of the compressor, are supplied from branches provided with reservoirs of air (stored at MP) and a pressure reducing manifold (see Figure 551-2-18 and Figure 551-2-19). An MP air plant and system supply air at required pressure for services and equipment such as, but not limited to, propulsion diesel starting, diesel generator starting, sea chest blow, whistle, pneumatic clutch, shaft brake, bow ramp hydraulic accumulators, cable tensioning, and tools.

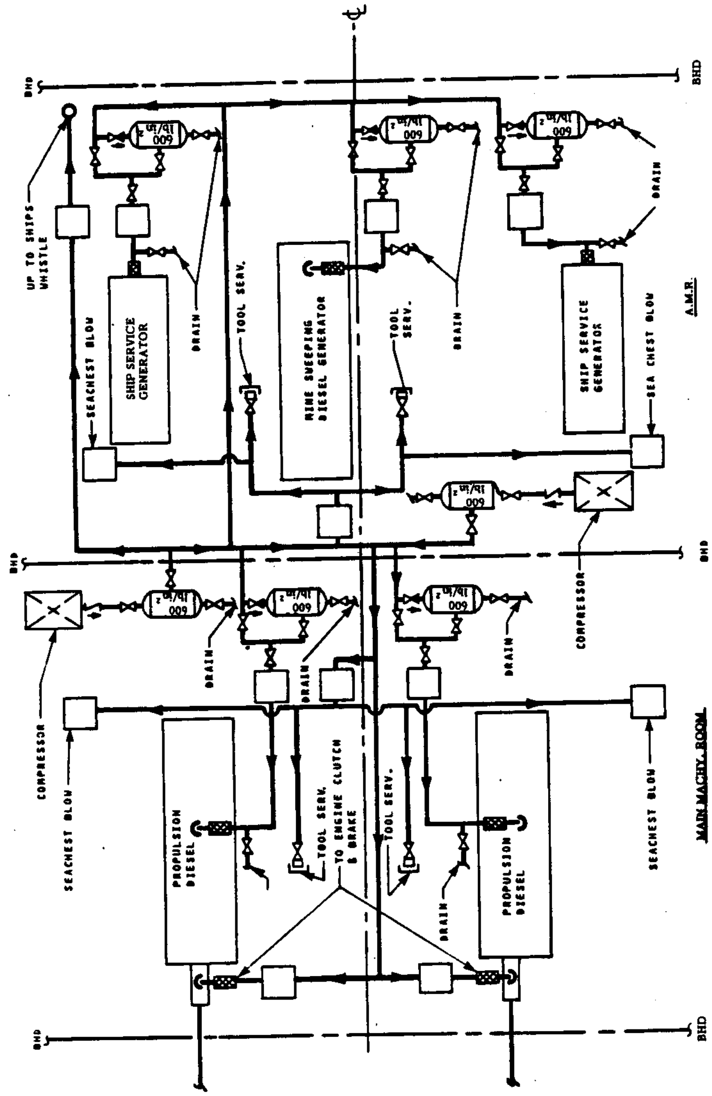


Figure 551-2-18 Typical Minesweeper MP Air System

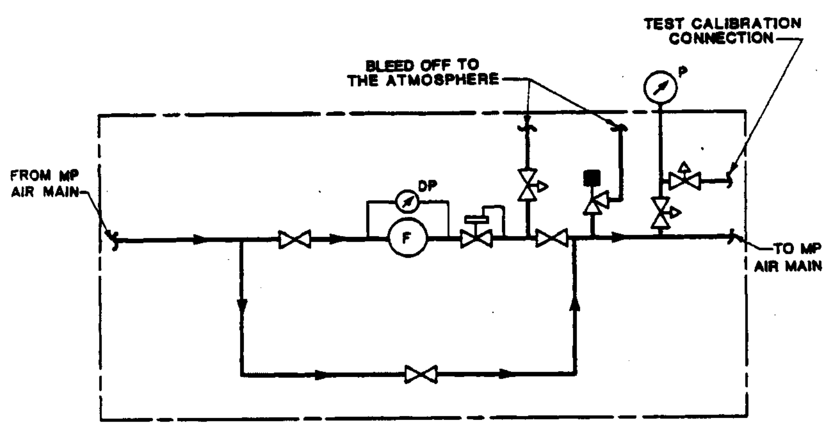


Figure 551-2-19 Typical MP Air Reducing Manifold

551-2.3.4.2 Diesel Engine Starting Air. Ships which have an MP air system installed normally start the diesel engines with that system. The MP air compressors charge the starting air tanks to 600 lb/in^2 pressure. Each engine, auxiliary or propulsion, is provided with starting air tanks. Cross connections between starting air tank discharges allow backup starting air for other diesel engines.

551-2.3.4.3 Sea Chests Blow Air. A branch from the MP air main provides compressed air for blowing sea chests clear of debris. A cutout valve separates the sea chest blow branch from the MP air main. Downstream of the cutout valve is a throttling valve and stop-check valve terminating in a hose connection complete with cap and stay chain. Located between the stop-check valve and the hose connection is a pressure gauge, a pressure relief valve, and bleed-off connection, as shown in Figure 551-2-20.

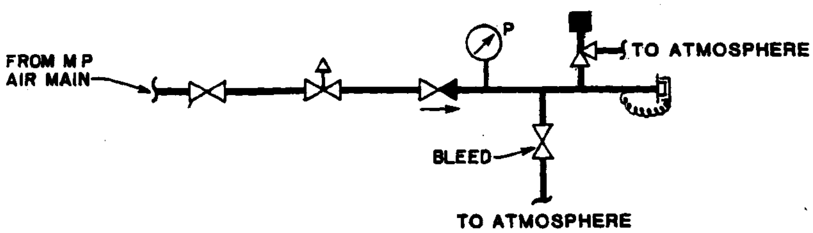


Figure 551-2-20 Typical MP Sea Chest Blow Connection

551-2.4 LP AIR PLANTS AND SYSTEMS

551-2.4.1 GENERAL. LP air plants and systems are designed for nominal operating pressure of 150 lb/in^2 and below. The function of an LP air system is to supply air at the required pressure and flow rate to meet all the demands of the various shipboard services. The LP air system is the most extensive and varied of air systems that shipboard personnel encounter. The selection and configuration of an LP air system reflects a ship type, class, and the best of design practices and criteria that existed at that time. Changes in ship types, classes and missions, along with increasing demands on LP air systems, by necessity were followed with corresponding changes in design practices and criteria. At present, two basic concepts in the design of LP air systems are installed, namely:

a. LP ship service air/control air concept

b. Vital/nonvital air main concept.

551-2.4.2 LP SHIP SERVICE AIR/CONTROL AIR CONCEPT. The following paragraphs describe in detail the LP ship service air/control air concept.

551-2.4.2.1 Overview. For small harbor, minor auxiliary, and support craft which have limited LP ship service and control air demands, air services are supplied from a higher pressure air system by way of a pressure reducing manifold. Such an LP compressed air system consists of a single LP air main supplied by the higher pressure air system with branches to the services. However, some installations of LP air systems aboard larger ships reflect the earlier concept of a combination of two separate LP compressed air systems, a ship service air system, and a control air system. Each of these separate systems has its own individual LP compressed air plants, LP air mains, and individual services. Refer to Figure 551-2-21 and Figure 551-2-22.

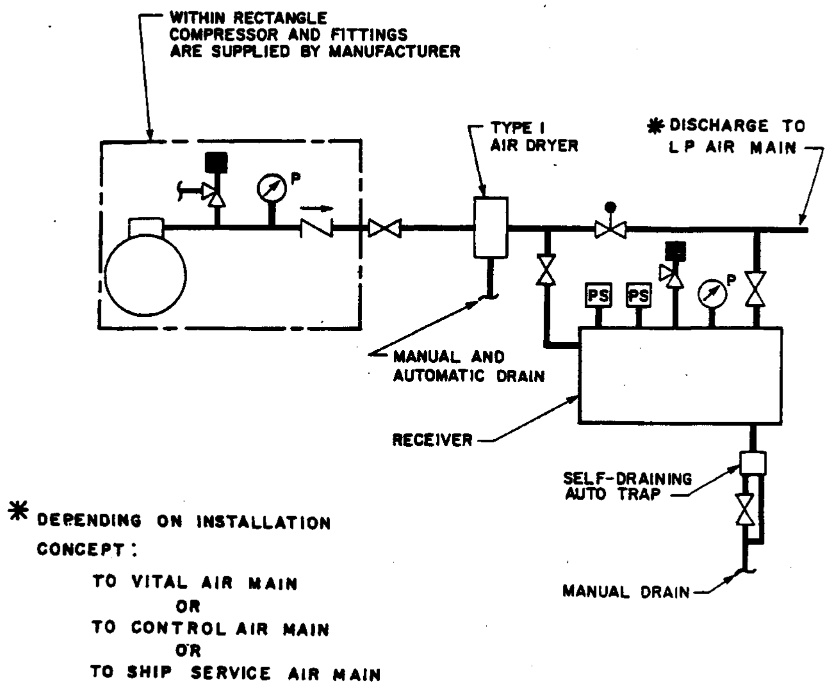


Figure 551-2-21 Typical LP Compressed Air Plant with a Reciprocating or Rotary Type Compressor

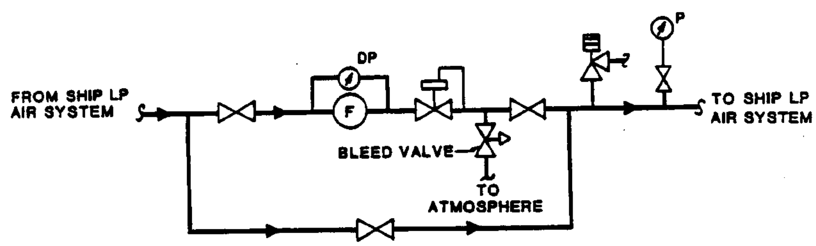


Figure 551-2-22 Typical LP Reducing Manifold

551-2.4.2.2 Air Plants. A typical LP compressed air plant consists of an LP reciprocating or rotary compressor, check valve, stop valve, type I dehydrator, receiver, and discharge to the air main, with assorted valves and pressure gauges and an electropneumatic pressure control system. The LP air compressors are provided with intercoolers and moisture separators. Relief valve protection is provided at the compressor. Each LP air compressor discharges into a dehydrator where additional moisture is removed. The refrigeration dehydrator (type I), forming part of the LP compressed air plant, reduces the dewpoint of moisture saturated air. An air receiver serves as a reservoir to take care of sudden or unusually heavy demands in excess of compressor capacity, dampens pulsations in the compressor discharge piping, and reduces compressor cycling.

551-2.4.2.3 Air Mains. The combination of systems, depicting this earlier concept of design practices and criteria, consists of two completely separate air mains. The control air main configuration consists of a single piping run through the machinery space, where at least one dedicated compressor plant serves as the primary air source (85 lb/in^2), and then extends forward and aft at one or more deck levels as necessary to provide service to all control air users. Similarly, the ship’s service air main configuration consists of a single piping run through the machinery space, where two or more other dedicated compressor plants serve as the source of air (125 lb/in^2 or 150 lb/in^2) and extends forward and aft at one or more deck levels as necessary to provide ship service air to the remaining LP air users. Cross-connected piping is installed from the ship service air main by way of a pressure reducing station to serve as a backup air supply for the control air system.

551-2.4.2.4 Control Air System. The control air system provides clean, oil-free, and dry LP compressed air for the more critical functions having the highest priority such as all air-operated valves, pneumatic controls, and equipment associated with the propulsion plant and the electronics dry air header by way of a control air main that extends the length of the propulsion plant spaces and branches from the main to the individual services. The control air supply to the electronics dry air header is provided by way of type III air dehydrators.

NOTE

Type III dehydrators are being phased out and replaced with type II.

551-2.4.2.4.1 The LP control air system delivers air at required pressures for services and equipment including, but not limited to: automatic combustion and feedwater controls, engine room and pilot house control stations, clutch and speed control, maneuvering valves, engine room cutoff valves, governor actuators, shaft brakes, and pitch systems. Various control air system configurations are installed. Some configurations may have as many as four compressed air plants where two air plants are installed in each machinery space. Cross connections are provided in the machinery spaces such that any or all four air plants can provide an air supply by way of the control air main to any and all services.

551-2.4.2.4.2 Generally, one air plant can provide the normal operating air demand of a machinery space. The second air plant cuts in only when the air demand exceeds the capacity of one air plant such as during a maneuvering evolution. Each control air plant has a pressure setting of 85 lb/in^2 and a minimum capacity of 50 scfm. Pressure switch controls are normally set to start one of the air plants when the system pressure drops to 65 lb/in^2 and to stop the air plant when the system pressure reaches 85 lb/in^2 .

551-2.4.2.4.3 The standby air plant cuts in only when the air demand exceeds the capacity of one air plant such as during a maneuvering evolution when the system pressure drops to 62 lb/in^2 . The pressure switch can be cut out by a selector switch which sets up the air plant for a continuously running load/unload mode. When operating in this mode, discharge air is bypassed to the suction side of the compressor during low load conditions. Additional assurance that an adequate air supply is available for emergency conditions is provided by a cross connection to the ship service LP air system in each machinery space. This automatic backup air supply is provided by way of a pressure reducing station which is set to supply air to the control air system when the pressure in the control air main drops below 60 lb/in^2 .

551-2.4.2.5 Ship Service Air System. The ship service air system supplies LP air by way of the ship service air main to all miscellaneous equipments and services which can tolerate and operate satisfactorily with interruption of the air service. These noncritical services may include the following:

a. Supply to hose connections for operation of pneumatic tools
b. Torpedo room services
c. Supply to the pneumatic tube dispatch system
d. Supply to hose connections for cleaning electrical equipment
e. Supply air to deck-edge elevator locks

f. Supply air to laundry equipment

g. Supply air for aviation lube oil blow-back

h. Supply to tank liquid level gauges

i. Supply to hose connections for spray guns in filter cleaning stations

j. Supply to the windshield wiper pressure tank

k. Supply to the underwater log trunk

l. Supply to filter lubricators of pneumatic hoists

m. Supply to hydraulic test stand and hose burst cabinet

n. Sonar dome services

o. Supply for sea chest blow

p. Blowing out dry piping of sprinkling systems

q. Chilled water system expansion tanks

r. ASROC launcher rammer motor services

s. Firemain services

t. Shop and machinery space services

u. Other services as required or specified.

551-2.4.2.5.1 The LP ship services air system may be served by as many as four LP air plants, each rated at 125 lb/in^2 or 150 lb/in^2 and 200 scfm or 100 scfm where two air plants are installed in each machinery space to supply all of the noncritical ship service air demands. All ship service air plants are cross-connected to the service air main to ensure an air supply to all users (see Figure 551-2-21).

551-2.4.3 LP VITAL/NONVITAL MAIN CONCEPT. Increasing demands for LP air has resulted in the inability of installed LP air systems to maintain the required minimum air pressures and flow rates to all vital services. The major contributing factor to this LP air system problem (other than increasing air demands) is the inability of a ship service air/control air concept installation to permit the distribution of air on a priority basis. To resolve this design deficiency, the LP vital/nonvital air main concept was developed.

551-2.4.3.1 Separated Air Mains. The idea of segregated vital and nonvital air mains was first applied as part of a cruiser/destroyer improvement program and was particularly aimed at ensuring reliability of the air supply to the propulsion control and electronics dry air main. This concept is applicable to all combatant ships, auxiliaries, and major support craft where supply to vital services is involved. The dry air improvement program provides Ship Alterations (SHIP-ALTS) for backfitting various type ships including CG, CGN, DD, DDG, FF, FFG, and LCC. At the present time, the LP air systems which were installed per the earlier design concept (LP ship service air/control air concept) are being modified by SHIPALT to reflect the vital/nonvital air main concept (see Figure 551-2-23).

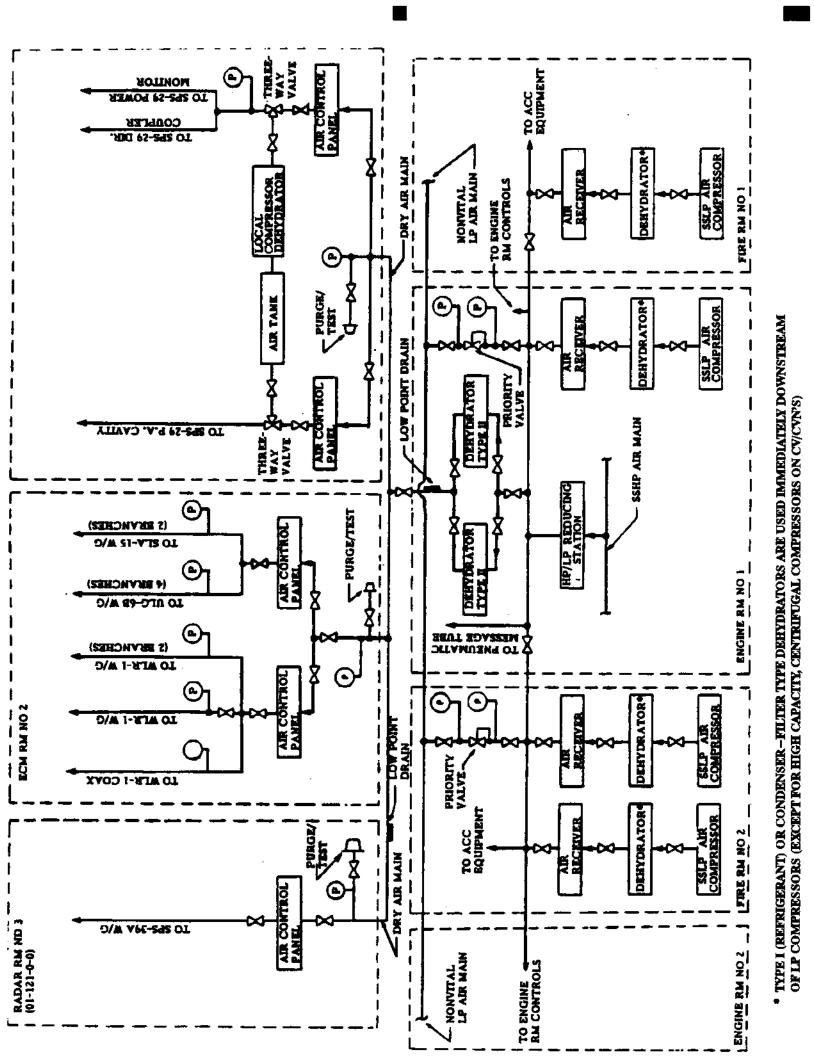


Figure 551-2-23 LP Air Plants and Systems Layout (Vital/Nonvital Air Main Concept)

551-2.4.3.2 Air Plants. There are two basic types of LP air plants which serve the vital/nonvital air main concept. The first type consists of an oil-free reciprocating, or rotary, water-flooded, helical screw compressor; a Type I (refrigerant) or Condenser-filter dehydrator and a receiver discharging to the LP service vital air main. There are two standard sizes for the reciprocating compressor (100 scfm or 200 scfm at 125 lb/in^2 or 150 lb/in^2), and only one standard size for the rotary, water-flooded, helical screw compressor (100 scfm at 125 lb/in^2).

551-2.4.3.2.1 The second type of LP air plant consists of an oil-free, 1,250 scfm, centrifugal compressor rated at 125 lb/in^2 ; a chilled water aftercooler, and receivers feeding the ship service main. Dewpoint of air in the ship service main is +50 to +60° F. A portion of the ships service main is protected by a dehydrator and has a dewpoint of -40° F.

551-2.4.3.3 Air Mains. An LP compressed air system configured according to the vital/nonvital air main concept has all of the ship's LP air plants discharge to the vital air main only. The vital air main, in turn, supplies all of the ship's LP air services. All vital air services are supplied directly from the vital air main while all nonvital services are supplied from the vital air main only by way of priority valves which discharge to the nonvital air main. When both the vital and nonvital air demands exceed the ship's entire LP system air capacity, the priority valves (set to start closing at 100 lb/in^2 and to be closed at 85 lb/in^2) respond to the resulting pressure loss in the vital air main by closing to isolate all airflow to the nonvital air main. Priority valves function to ensure that the entire LP air capacity of the ship is made available for vital services before allowing any flow of air to the nonvital air main (see Figure 551-2-24). Typical shipboard configurations of both the vital and nonvital air mains are as follows:

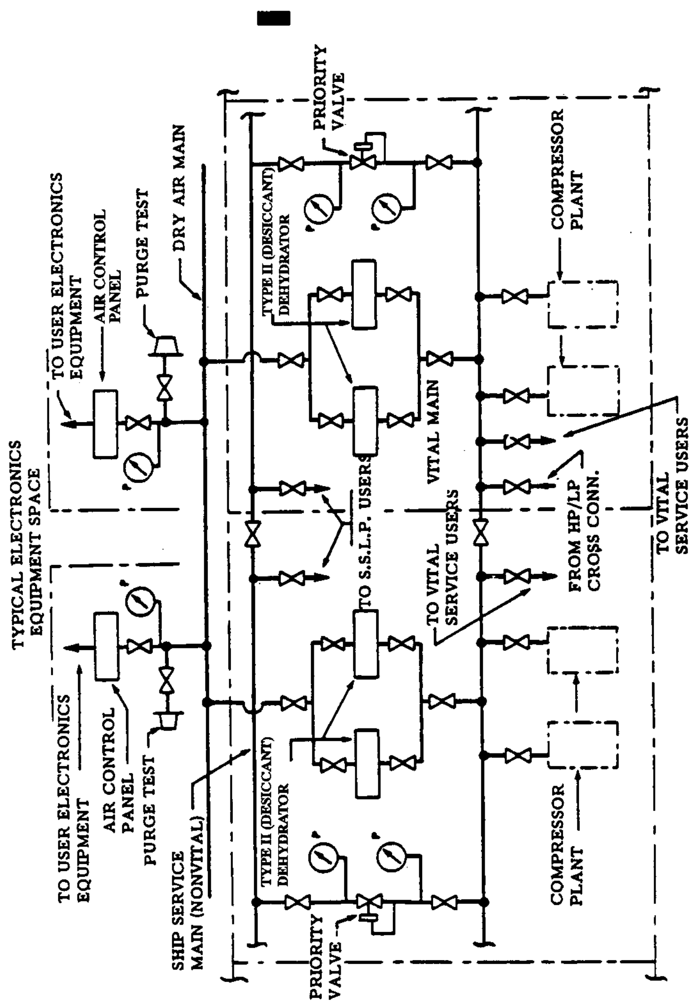


Figure 551-2-24 Typical LP Air System for Cruisers/Destroyers Utilizing Vital/Nonvital Air Main Concept

a. Aircraft Carriers (a combined vertical and horizontal loop). The forward and aft horizontal loop is located on the galley deck and is cross-connected at its approximate midpoint. The lower horizontal main of the vertical loop runs forward and aft on the third deck. The lower main and the upper horizontal loop are connected by risers at the approximate endpoints and midpoint. The extreme forward and aft spaces of a ship are served by single main extensions of the loop where a loop is provided. Branches, with root valves from the main, provide air to user services.

b. Destroyers, Cruisers, Frigates. A single horizontal main extends through the machinery spaces and on the second deck forward and aft of the machinery spaces. For other large ships which have port and starboard passageways, the LP air nonvital main is normally a horizontal loop with cross connections. Since it is not advantageous to extend the loop beyond the passageways, the extreme forward and aft spaces of the ship are served by single main extensions from the loop. Branches, with root valves from the main, provide air to user services.

551-2.4.3.4 Air Main Cross Connections. Originally, the vital/nonvital air main concept was applied to reciprocating compressor air plants only because large-size priority valves (3 inches) were not available for use with the 1,250 scfm centrifugal compressor air plants. Moreover, it was considered that the capacity of the 1,250 scfm plant was adequate to handle both vital and nonvital air load on aircraft carriers. However, load analyses on recent design aircraft carriers indicate that the total connected nonvital load far exceeds the specified centrifugal compressor capacity. For this reason, the concept of vital and nonvital air mains is a current design practice for aircraft carrier and has been backfitted in CV-59, CV-63, and CV-64. These ships received reciprocating nonlube compressors with type I dehydrators to discharge to a Propulsion Control Air (PCA) main.

551-2.4.3.4.1 The PCA supplies air to the propulsion plant and is arranged with priority valves set at 95 lb/in^2 to provide air to the vital main. Six to eight compressors per ship allow air in excess of propulsion plant needs to supply vital services user requirements during casualties to centrifugal plants or during in-port periods when marginal shore power is available to operate the large motors of the centrifugal compressors.

551-2.4.3.4.2 The recent design aircraft carrier, CVN-70, has cross connections between the LP service air plants and the O_2 N_2 LP air plants. These cross connections enable either system to augment the other if necessary. Other aircraft carriers (such as CV-59, CV-61, and CV-62 that have O_2 N_2 LP air plants and LP service air plants, which presently are not cross-connected) will be provided cross-connects by SHIPALT. An emergency backup source of air is cross-connected to the vital air main from the HP air system by way of a 3,000/80 lb/in^2 pressure-reducing manifold. This feature makes HP air, as well as all of the LP system capacity, available to the vital services only after the priority valve (set point at 85 lb/in^2) isolates the nonvital air main.

551-2.4.3.5 Vital Air Services. All vital air services are supplied from the vital air main (see Figure 551-2-23 , Figure 551-2-24 and Figure 551-2-25). The following services are considered vital to the ship's mission:

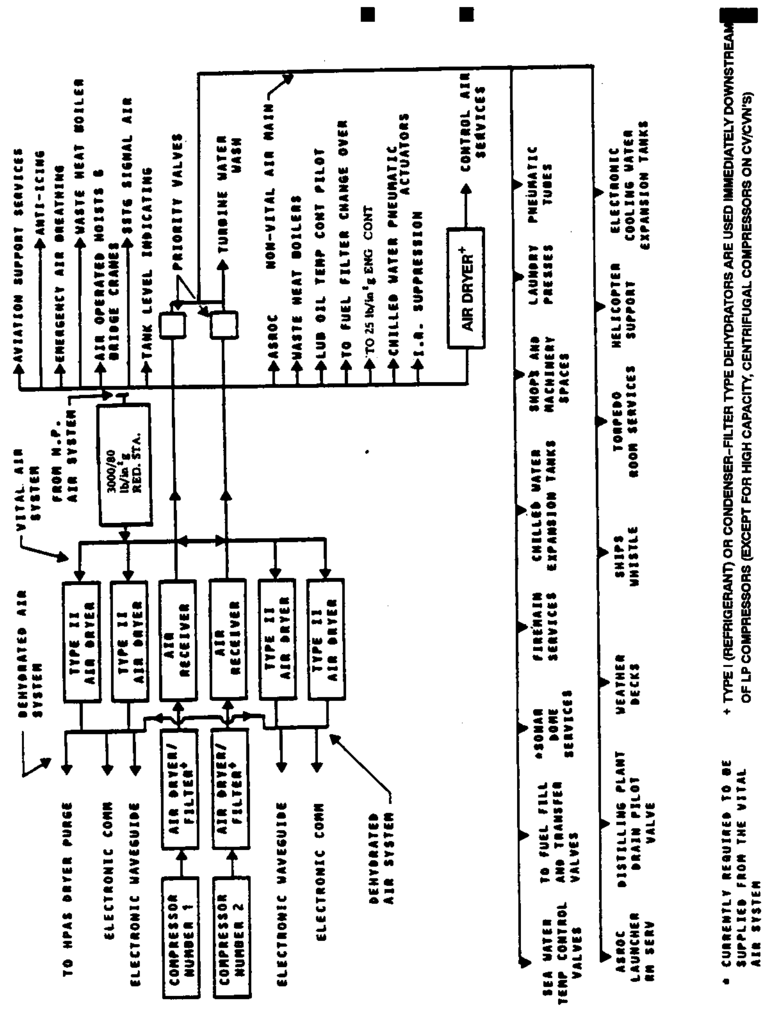


Figure 551-2-25 LP Air System Functional Diagram (Vital/Nonvital Air Main Concept)

a. Air-conditioning plant control by way of an air pressure-reducing manifold and moisture separator.

b. Air-operated valves and controls associated with the propulsion plant, except where valve operation requires the use of HP air.

c. Combustion and feedwater control air by way of a moisture separator as either the normal source or standby source.

d. Air-operated hoists and bridge cranes for weapons (CV's use nonvital air per SHIPALT 6277), by way of a filter/regulator/oiler equipped with metal bowl guards.

e. Sonar dome pressurization service.

f. Tank level indicating service.

g. LP emergency air breathing service (CV's use nonvital air per SHIPALT 6277). Air is supplied to the emergency air breathing service from the LP air system by way of the vital service air system and from the HP air system. A globe valve and EAB stations are installed in that order (see Figure 551-2-16).

h. Air-operated valves and controls for air deballasting system.

i. Air-operated valves and control for PRAIRIE and MASKER air subsystems.

j. Engine room and pilot house control stations.

k. Clutch and speed control.

l. Aviation support:

   1 Aircraft elevator locks

   2 Catapult steam accumulator fill and blowdown, and through heating control valves by way of a 125/100 lb/in^2 g reducing manifold

   3 Catapult control air charging panel

   4 Arresting gear anchor damper system valves

   5 Catapult steam riser, air-operated, quick closing cutout valves

   6 Barricade tensioning air motor hose valve stations

m. Electronics dry air users such as radar and antenna wave guides supplied via the Dry Air Main

551-2.4.3.6 Electronics Dry Air Main. On ships having multiple dry air users, a dedicated dry air main is installed to supply clean, oil-free, dry air to radar waveguides and other electronic equipment. Supply to this main is from the vital main by way of type II (desiccant) dehydrators installed in parallel so that one serves as a 100 percent standby for the other. In large ships with extensive air demands, four dehydrators are installed and the air main can be split, for casualty control. The dry air main terminates at air control panels which control and regulate pressure to electronic user equipment. The design types and classes characteristics of all air control panels are shown in Table 551-2-1.

a. Type I Panels: Typical users URA-38, WRT-1 and WRT-2, SPS-39, ULQ-6, WLR-1, SPS-40 waveguides.

b. Type II Panels: Typical users SPS-40 cavity, SPG-51 and SPG-60.

c. Type III Panels: Typical users SPG-55.

d. Special: Typical users SPS-32 and SPS-33, SMQ-10 (flow rates possible to 20 scfm at less than 1 lb/in^2).

Table 551-2-1 PRESSURE GAUGE, FLOWMETER, PRESSURE REGULATOR SELECTION AND SETTING REQUIREMENTS BY TYPE AND CLASS FOR AIR CONTROL PANELS

PANEL		INTERMEDIATE PRESS. REG		INTERMEDIATE PRESS. GAUGE	FLOWMETER	OUTLET PRESS. REG		OUTLET PRESS. GAUGE
TYPE	**CLASS**	**INLET PSI**	**OUTLET PSI**	**PRESS.**	**FLOW RANGE**	**INLET PSI**	**OUTLET PSI**	**PRESS. RANGE**
I	A	80 - 150	50 +/- 2	0 - 100	0 - 10	50	0 - 10 +/- 1/4	0 - 15
	B	80 - 150	50 +/- 2	0 - 100	0 - 10	50	10 - 20 +/- 1/4	0 - 30
	C	80 - 150	50 +/- 2	0 - 100	0 - 10	50	20 - 30 +/- 1/4	0 - 60
II	A	80 - 150	70 +/- 2	0 - 160	0 - 10	70	25 - 40 +/- 1/4	0 - 60
	B	80 - 150	70 +/- 2	0 - 160	0 - 10	70	40 - 60 +/- 1/4	0 - 100
III	A	80 - 150	75 +/- 2	NA	0 - 15	NA	NA	0 - 160
SPCL	SPECIAL APPLICATIONS WHERE THE PRESSURE OR FLOW RATE REQUIREMENTS OF THE USER EQUIPMENT DIFFER FROM THOSE OF TYPE I, II OR III. SPECIFY COMPONENTS AS NECESSARY.							

551-2.4.3.6.1 In addition, equipment such as SPS-48 and SPS-49 are supplied with panels designed for 80 to 125 lb/in^2 . Each panel is equipped with sampling connection, humidity indicator, flow meter, pressure gauges, and valvings to permit user equipment personnel to monitor their equipment (see Figure 551-2-26).

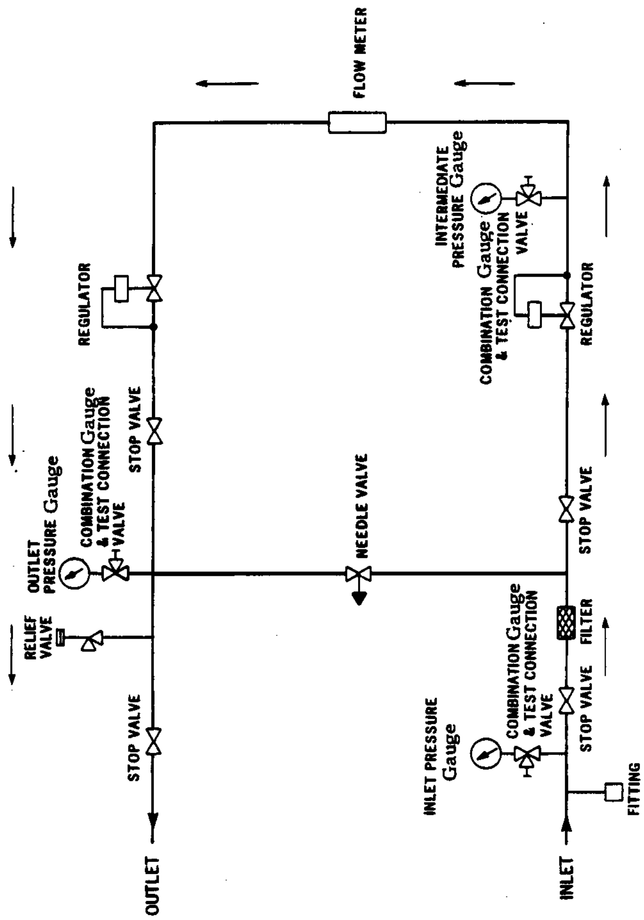


Figure 551-2-26 Type I, II, III and Special Dry Air Control Panel Schematic Flow Diagram

551-2.4.3.6.2 In order to ensure the reliability of a dry air supply to electronic services, local, dedicated dehydrators or local, dedicated compressor-dehydrators may be provided. These local, dedicated dehydrators are supplied from the vital air main and intended for emergency use when battle damage or casualties result in failure of the central dry air system. The local compressor-dehydrators, on the other hand, include an air compressor which enables operation of the unit completely independent of the ship's air supply. These units generally include a pressure regulating valve to provide required outlet pressure. The outlet air from the local dehydrator or local compressor-dehydrator is connected between the air control panel outlet and the electronic user equipment. Shutoff valves are provided to permit the use of either the air control panel or the local dehydrator outlet air for pressurization of the electronics equipment (see Figure 551-2-27 and Figure 551-2-28).

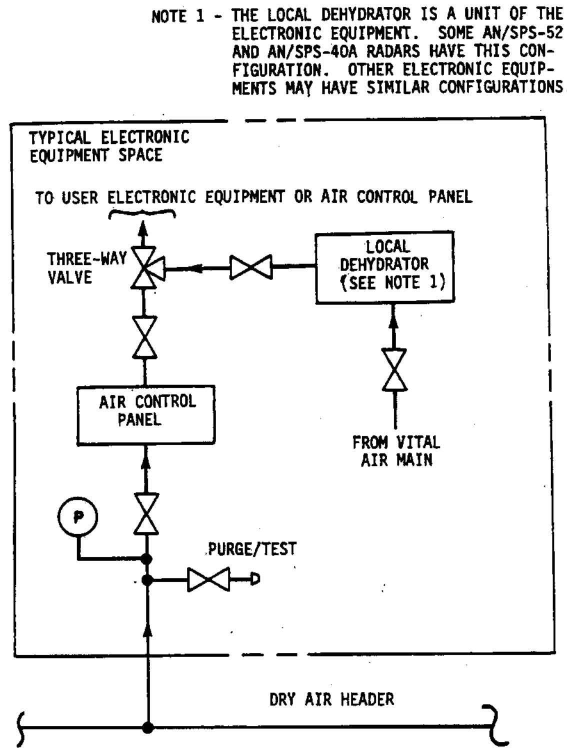


Figure 551-2-27 Typical Central Dry Air System/Electronics Equipment Provided Dehydrator Interface

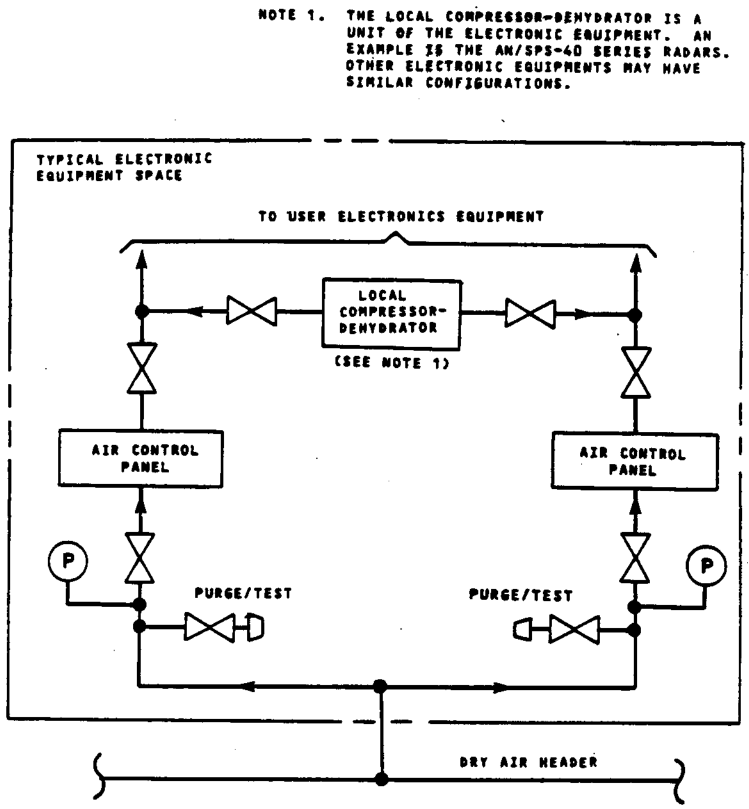


Figure 551-2-28 Typical Central Dry Air System/Electronics Equipment Provided Compressor-Dehydrator Interface

551-2.4.3.7 Nonvital Air Services. The nonvital service air main is supplied air at required pressure for nonvital systems and equipment including, but not limited to:

a. Operation of pneumatic tools with hose outlets in propulsion plant spaces, auxiliary plant spaces, on weather decks, in all shops, and in other locations where pneumatic service is required. All pneumatic tool air outlets are supplied at a maximum pressure of 90 lb/in^2 from a filter/regulator/oiler assembly equipped with metal bowl guards.

b. Ventilating of torpedoes with outlets located in the torpedo workshop provided with, in the order given, a stop valve, strainer, separator, pressure reducing valve (having an adjustable LP setting from 25 to 50 lb/in^2), relief valve, pressure gauge, and a male hose outlet with cap and stay chain suitable for 5/8-inch pneumatic hose. The assembly shall include metal bowl guards.

c. Cleaning electric machinery, instruments, and electric appliance controls with hose outlets in propulsion plant spaces, auxiliary plant spaces, electrical plant spaces, and other spaces where electric machinery is installed. A cutout valve and moisture separator shall be installed for each outlet or group of outlets. Each outlet is provided with a hose and blowgun. The blowgun is fitted with an orifice designed for a discharge pressure of 25 lb/in^2 .

d. Blowing out pilot-tube type rodmeters for log nulling system and seacock for remote draft indicator system with outlets convenient to the rodmeter and seacock installation.

e. Cleaning fixed carbon dioxide indicator systems.

f. Drying rocket launchers, after wetting down dud rockets, with outlets adjacent to such apparatus.

g. Charging pump air chambers, hydraulic cylinders, and chilled and hot water expansion tanks through stop-check hose valves.

h. Air supply for dental operating room, prosthetic laboratory, and eye, ear, nose, and throat treatment room by way of a stop-check valve, 1-1/2 ft^3 receiver, cutout valve, air pressure reducing valve 100/50/5 lb/in^2 , relief valve, filter, and branch lines to each chair and outlet in these spaces.

i. Blowing out sea chests if a steam line is not available. Outlets are centrally located so each can serve as many sea chests as practicable. The following are installed in the order enumerated at each outlet: needle valve, stop-check valve, gauge, relief valve set at 40 lb/in^2 , bleed-off connection, and capped hose connection.

j. Charging pilothouse window-washing supply tank.

k. Blow back of fueling hose [Diesel Fuel Marine (DFM) and JP-5] with hose outlets at fueling stations on fleet oilers and other ships which supply escorts with oil. A cutout valve, gauge, bleed-off connection, and capped hose connection are installed in that order.

l. Blowing out dry piping of sprinkling systems.

m. Laundry equipment air, reduced to 80 lb/in^2 as required for the various services.

n. Hose outlets in the filter cleaning shop air at 50 lb/in^2 .

o. Nitrogen booster pump supply.

p. Standby supply for sewage holding tank aeration.

q. Helicopter aircraft services and maintenance (100 lb/in^2 for hoist and 50 lb/in^2 for helo shops).

r. Mk 12 Mod 5 torpedo tubes, a service supply line to the torpedo tube magazine.

s. All air-operated hoists are supplied from a filter/regulator/oiler assembly equipped with metal bowl guards.

t. Air supply to whistles on diesel and gas turbine-driven ships.

u. Compartment air testing, with outlets in number and location so that every air-test fitting can be reached with a 100-foot length of hose.

v. For operation of the pneumatic tube system, air is supplied at 5 lb/in^2 pressure to the tube terminals through a pressure reducing valve and air receiver.

w. Lube oil coast-down pump (in addition to the HP air supply), air is also supplied from the LP ship service air system for testing the air motor. This line includes a check valve and a normally locked-shut isolation valve to guard against pump improper operation.

551-2.5 INDEPENDENT SPECIAL AIR SYSTEMS

551-2.5.1 GENERAL. Special LP compressed air systems require provision of independent compressed air supply plants usually because their capacity and pressure service requirements are not consistent with the normal ship service compressed air system capacities and pressures. A discussion of such systems is contained in the following paragraphs.

551-2.5.2 DIVER'S AIR SYSTEM. The shipboard diver's air system provides compressed air for use by underwater divers. This compressed air may charge the Self Contained Underwater Breathing Apparatus (SCUBA) cylinders or charge an onboard accumulator which provides air to the diver(s) by way of air hose(s) as in the Hardhat Surface Supplied diving operation.

551-2.5.2.1 The diver's air supply may originate from either an air compressor, a bank of HP air flasks, or a combination of both. Regardless of the source, the air shall meet certain established standards of purity, shall be supplied in an adequate volume for breathing, and at a flow which will properly ventilate the diver's helmet or mask. The air shall also be provided at sufficient pressure to overcome the bottom water pressure and the pressure losses due to flow through hose, fittings, and valves.

551-2.5.2.2 Air supply requirements depend upon specific factors of each dive such as depth, duration, level of work, number of divers being supported, and the type of diving system being used. Air, if taken directly from the atmosphere and pumped to the diver, may not meet the purity standards established by the Bureau of Medicine (BUMED). The air itself may be contaminated by engine exhaust or chemical smog or even initially pure air may become contaminated while passing through the compressor system. These standards are for nonsaturation dives and are measured at standard temperature and pressure, dry (0° C, 760 mm Hg). The quality of air, as measured at the final outlet valve of any supply system, shall conform to the following limits:

a. Oxygen concentration: 20 to 22 percent by volume

b. Carbon dioxide: 1,000 ppm maximum

c. Carbon monoxide: 20 ppm maximum

d. Total hydrocarbons other than methane: 25 ppm maximum

e. Oil, mist, particulates: 5 mg/m^3 maximum.

551-2.5.2.3 To meet these standards, oil-free compressors shall be used, or the air supplied by a standard compressor shall be passed through a highly efficient filtration system. The ship service air systems found onboard usually contain excessive amounts of oil and are not suitable for diving without being filtered. Air taken from any machinery space or downwind of the exhaust from an engine or boiler shall be considered to be contaminated.

551-2.5.2.4 Most air supply systems used in Navy diving operations include at least one air compressor as a primary source of air. Reciprocating compressors are the most common compressors found in air-supplied diving operations. They are capable of providing capacities sufficient to support almost any surface-supplied air diving operation and recompression chamber. This type of compressor is also capable of attaining pressures high enough to charge SCUBA cylinders and HP cylinder banks, although at these pressures the capacity is normally low.

551-2.5.3 GAS-TURBINE BLEED AIR SYSTEM. The bleed air system is supplied by connections from each propulsion and generator gas turbine compressor. Bleed air from each turbine is controlled by a regulating valve that senses the pressure in the bleed air main. The bleed air main supplies the gas turbine starting and anti-icing systems and in some installations, also supplies the PRAIRIE and MASKER subsystems. Some gas turbines use the bleed air system as a control mechanism to keep the engine from surging during low power operation. In this case, the bleed air should not be used simultaneously for other customer services unless the manufacturer states otherwise. For further discussion of the gas turbine bleed air system when used as the supply source for PRAIRIE and MASKER air subsystems, refer to paragraphs 551-2.5.4.6.2 through 551-2.5.4.6.5.

551-2.5.4 PRAIRIE/MASKER AIR EMISSION SYSTEM. The PRAIRIE/MASKER air emission system was developed to reduce the detectability of Antisubmarine Warfare (ASW) ships by enemy sonar and to improve the ship's own ASW effectiveness by reducing platform noise. The PRAIRIE subsystem reduces high-speed propeller cavitation and noise, while the MASKER subsystem reduces machinery noise radiating from the hull. The PRAIRIE/MASKER air emission system for ASW destroyers (other than gas turbine powered ships which utilize bleed air), for example, consists of two steam-driven turbo compressors which supply air to two pairs of MASKER emitter belts and through a cooler, a shaft rotary air seal, and through the shaft to the PRAIRIE propeller (see Figure 551-2-29 and Figure 551-2-30).

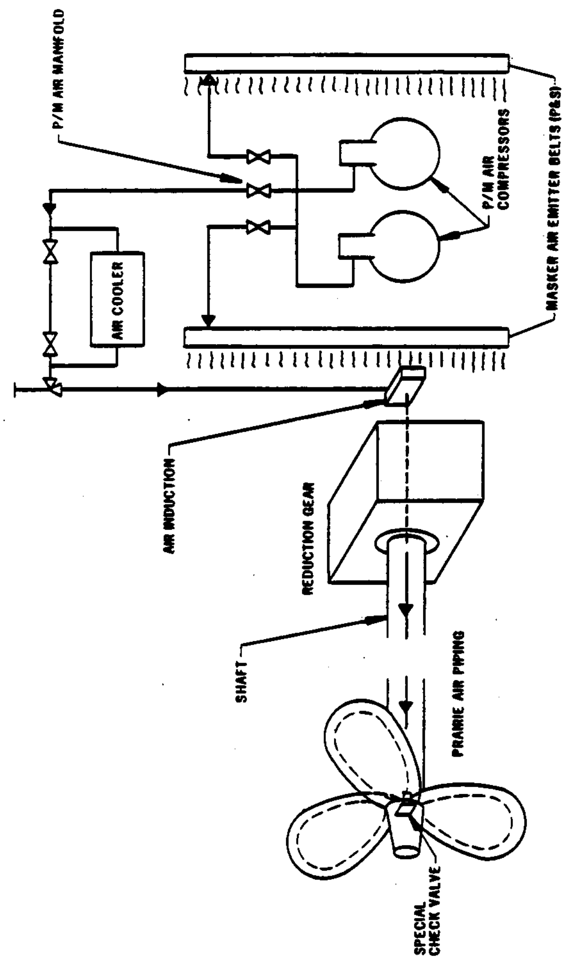


Figure 551-2-29 PRAIRIE/MASKER Compressed Air System

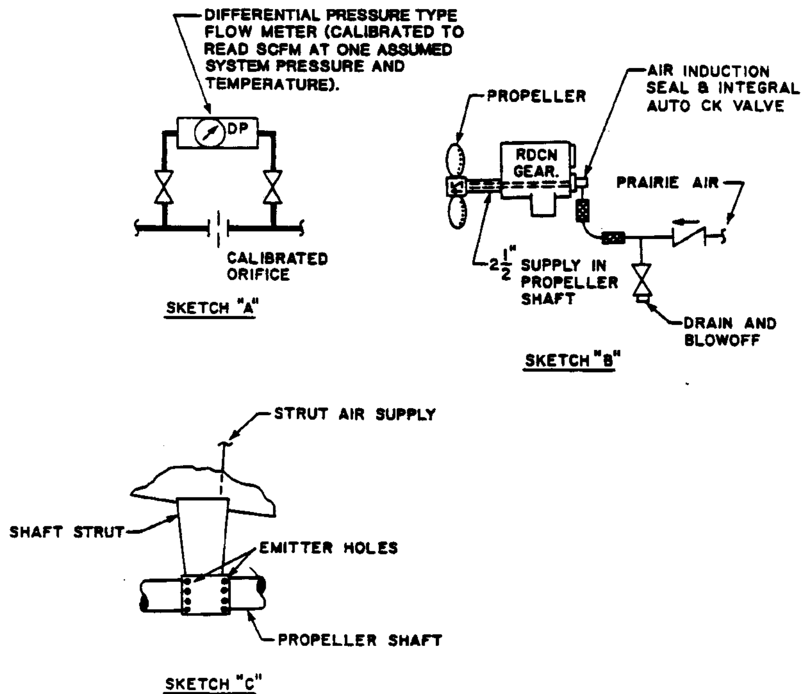


Figure 551-2-30 PRAIRIE/MASKER Compressed Air Details

551-2.5.4.1 Air Source. Each compressor is a compact, high-speed (about 40,000 rpm) centrifugal type unit which delivers a large volume of air at high temperature but low pressure (1,400 scfm at 350° F and 25 lb/in^2). Some compressor bearings are water lubricated, requiring a fresh water lubricating system with a motor-driven pump, supply tank, and saltwater heat exchanger. The water lubricating system takes makeup water from the condensate system. The control air system, electric-operated controls, and other support systems are also utilized. Steam (600 or 1,200 lb/in^2) is used to drive the turbine that is on a common shaft with the compressor impeller. The rated steam consumption is 3,100 pounds per hour per unit.

551-2.5.4.2 Emitter Belts. Air is emitted externally to the sea about the ship's hull by way of MASKER emitter belts (fabricated by flattening a 3-inch perforated pipe to 1-1/2 inches, or by cutting a 3-inch pipe longitudinally in half and securing it to a backing plate) fastened to the shell of the ship. MASKER emitter belts on some ships have been attached with epoxy to electrically isolate the belt from the hull. In some cases the epoxy bond has failed. The use of epoxy to bond belts to the hull is no longer permitted. Where failed bonds are found, belts should be welded.

551-2.5.4.3 PRAIRIE Air Supply. Air is also supplied to the PRAIRIE subsystem by way of a saltwater heat exchanger (to reduce the air temperature to 150° F) through a rotary union device attached to the main reduction gear (designed to direct the air into the piping within the propeller shafting) and then to a specially designed propeller with air channels and holes in the leading edges of the propeller blades.

551-2.5.4.4 PRAIRIE Subsystem. Propeller cavitation results from the reduced pressures created at the tip and suction surfaces of the propeller blade as it rotates through the water. Low pressure at these areas causes the water to vaporize in the form of minute bubbles that collapse immediately upon entering regions of higher pressure, producing a sharp noise. PRAIRIE injects positive-pressure air bubbles into the cavitating area and absorbs much of the water vapor as it forms, preventing the bubble collapse associated with cavitation and thus reducing the noise.

551-2.5.4.5 MASKER Subsystem. MASKER is the bubble screening method for the suppression of hullborne sound produced by the machinery spaces. Noise is reflected, absorbed, and scattered by the bubble screen. This method is explained by various scientific theories. There is a resonant bubble theory which concludes that if the wavelength of the noise is equal to, or is some harmonic of the bubble size, the noise energy will be trapped inside the bubble. Simply, the seawater surrounding an air bubble is of a higher density than the air bubble. Sound energy travels faster in a more dense medium.

551-2.5.4.5.1 When the sound energy strikes an air bubble, several things happen. First, due to the spherical nature of an air bubble, much of the sound energy is scattered. Second, the sound energy that penetrates the air bubble is reduced in velocity due to the density change. As the bubble absorbs the sound energy, the energy will cause a deflection in the bubble or be transformed into heat energy. Thus, less sound energy (noise) is transmitted from the hull.

551-2.5.4.5.2 Most of the holes in MASKER belt designs are 3/64-inch diameter. These holes require frequent cleaning to remove sea growth and silt deposits which clog the opening. SHIPALT's exist to retrofit most classes of ships with an improved electrically isolated belt which has proven to significantly reduce the sea growth clogging. All new construction ships from 1985 on should have received this improved belt design.

551-2.5.4.6 Supply Air Systems. The PRAIRIE/MASKER system may be a separate or a combined system. The PRAIRIE and MASKER subsystems may each have their own dedicated supply air system, or one supply air system may provide air to both the PRAIRIE and MASKER subsystems.

551-2.5.4.6.1 The type of supply air plant is determined by the ship's propulsion plant. On gas turbine propelled ships, bleed air from the gas turbines can be used to supply the PRAIRIE/MASKER system. Conventionally powered steam ships utilize a water-lubricated, centrifugal air compressor. Nuclear-powered ships provide air, by way of an electric motor (300 hp) driven, oil-lubricated, centrifugal compressor, to the PRAIRIE subsystem. The air emission system provided on nuclear-powered ships is limited to the PRAIRIE subsystem only.

551-2.5.4.6.2 The Bleed Air System (BAS) is supplied by bleeding air off the compressor section of each gas turbine engine. (See Figure 551-2-31 for typical DD-963 class layout.) Bleed air from each turbine is controlled by a regulating valve that senses the pressure in the bleed air main. The bleed air main supplies the gas turbine starting systems, the anti-icing systems, and the PRAIRIE and MASKER subsystems.

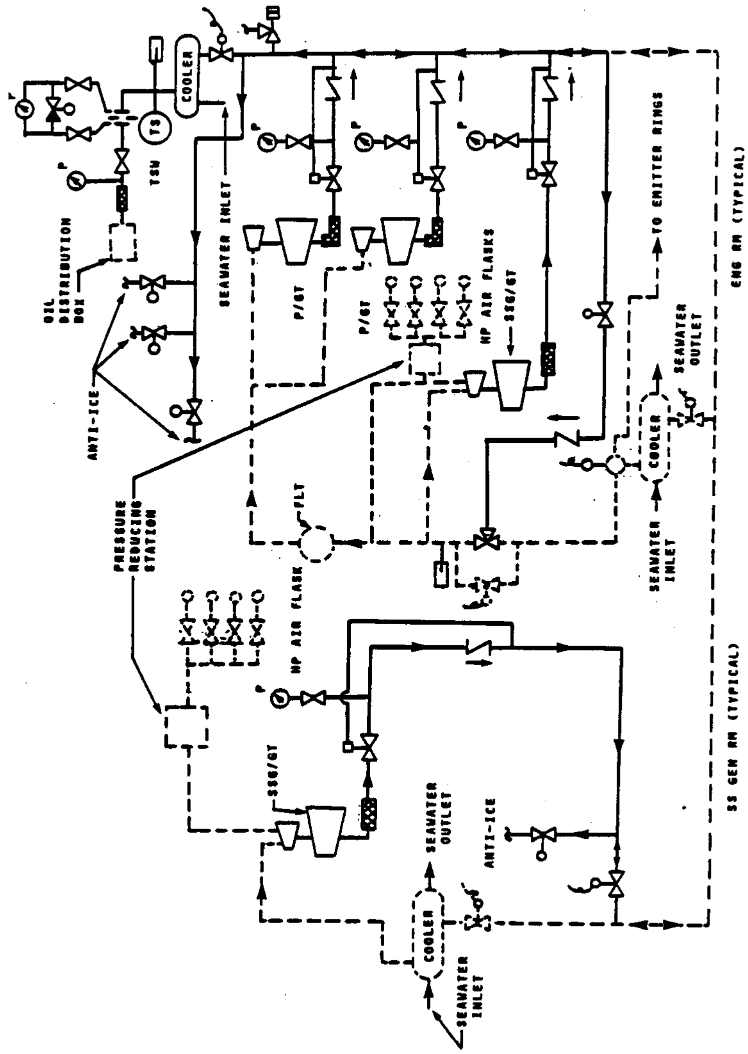


Figure 551-2-31 General Arrangement Bleed Air System (DD-963 Class)

551-2.5.4.6.3 Bleed air is supplied to the MASKER subsystem through a seawater-cooled heat exchanger which reduces air temperature to 400° F maximum for FFG-7 class, 190° F maximum for all others. The reduction in temperature was designed not to exceed limitations of the MASKER air piping downstream of the cooler. Worst-case conditions were used for design; actual operating conditions are significantly cooler than the maximums specified. Bleed air for PRAIRIE is cooled similarly to less than 150° F to protect the automatic check valve and shaft seal from excessive temperature. Bleed air used for gas turbine starting air is cooled to comply with the starter manufacturer's requirement that start air not exceed 450° F on all except FFG-7 class.

551-2.5.4.6.4 Bleed air is directed to either girth emitter belts or gas turbine starting by way of a solenoid-operated diverter valve, which permits use of a single cooler for cooling the air to both services. A mixing valve when installed, permits blending hot bleed air with the cooled bleed air when used for starting, to obtain a temperature necessary to prevent thermal shock. Bleed air for PRAIRIE is supplied from the cooler through a flowmeter to the orifices in the propeller blades. Passage is provided from the flowmeter to the propeller blades by way of the oil distribution box of the controllable pitch propeller.

551-2.5.4.6.5 Bleed air for the strut emitters is supplied from the MASKER BAS. Anti-icing bleed air is supplied (without cooling) from the BAS to the turbine air intake ducts. When the flow of the bleed air into the intake ducts is controlled automatically, a temperature sensing device opens a solenoid valve at 38 + 3° F to allow bleed air into the air intake ducts. In the event that insufficient bleed air is available to meet the requirements of both the MASKER and the anti-icing, the anti-icing system should be given priority over the MASKER subsystem.

551-2.5.4.6.6 Steam-driven centrifugal air compressors are utilized to supply air to both PRAIRIE and MASKER subsystems. The system diagram for an FF-1052 class ship is shown on Figure 551-2-32. The system allows for operation using one compressor or both compressors together supplying air through a cross connection manifold to a header. A silencer is provided on the inlet side of each compressor. At each compressor discharge, a blowoff branch line with control valve is provided. The blowoff lines terminate in the uptakes. A flow measuring orifice with pressure gauge taps is installed downstream of each blowoff branch line. Branches from the common main will supply PRAIRIE air to the propeller blades by way of passages in the reduction gear shaft and propulsion shafting. The exception to this is USS GLOVER (FF-1098) which provides air to a shroud around the propeller instead of holes in the propeller blade.

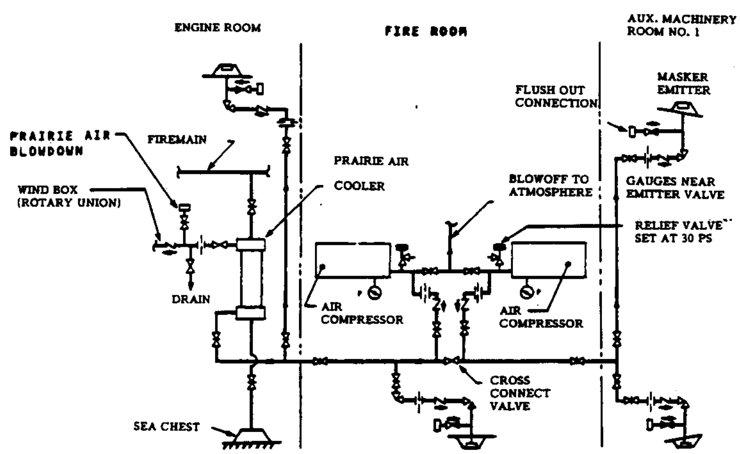


Figure 551-2-32 Dedicated Air Compressor Supply (Typical Arrangement from FF-1052 Class)

551-2.5.4.6.7 Nuclear-powered ships utilize two-stage, 300 HP motor-driven, centrifugal air compressors to supply PRAIRIE air. MASKER air is not provided. The ship has two compressors; however, only one is required to supply 45 lb/in^2 to the PRAIRIE subsystem. Automatic controls are utilized to provide automatic operation of the compressor. The discharge from the compressor is cooled, then distributed to each shaft where a rotary seal directs the air down the shaft to the propeller.

551-2.5.4.6.8 System components are shown in Figure 551-2-33 for all except USS GLOVER (FF-1098). PRAIRIE air is supplied to the reduction gear shaft by way of a seawater-cooled aftercooler, flow control valve, and a remote-reading flowmeter. The aftercooler is required to protect the automatic check valve and shaft seal at the connection to the reduction gear shaft from excessive air temperature. USS GLOVER (FF-1098) delivers air directly to a shroud around the propeller which does not require cooling the air.

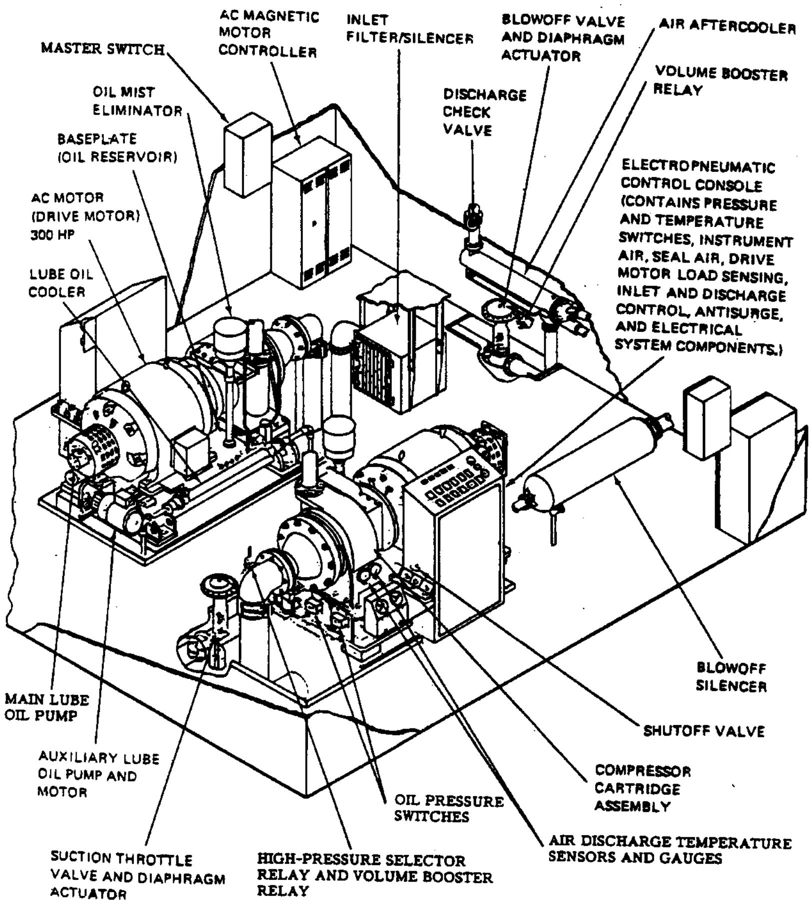


Figure 551-2-33 CGN-38 Class Compressor Components

551-2.5.4.6.9 MASKER air is supplied from the compressor cross connections to port and starboard girth emitter belts by way of branch lines, each provided with a flow control valve and a differential type flowmeter. A hull stop valve, check valve, and flushing connection are provided on each branch.

551-2.5.5 AIR FOR SEWAGE COLLECTING, HOLDING, AND TRANSFER. A Collecting, Holding, and Transfer (CHT) tank aeration system is installed to prevent sewage solids from settling out on the tank bottom and becoming anaerobic. Aeration of the tank is accomplished by either an air aspiration system or a compressed air system.

551-2.5.5.1 The air aspiration system consists of a recirculating pump installed outside the tank. This pump takes suction from the bottom of the tank and discharges through an air aspirator back into the tank along the bottom. Air is drawn into the sewage stream by the jet suction effect. This will aerate and mix the tank contents. The air supply line of the aspirator terminates in the weather. A compressed air aeration system may be installed which is capable of supplying the required airflow to the sewage by way of air diffusers (as shown in Figure 551-2-34).

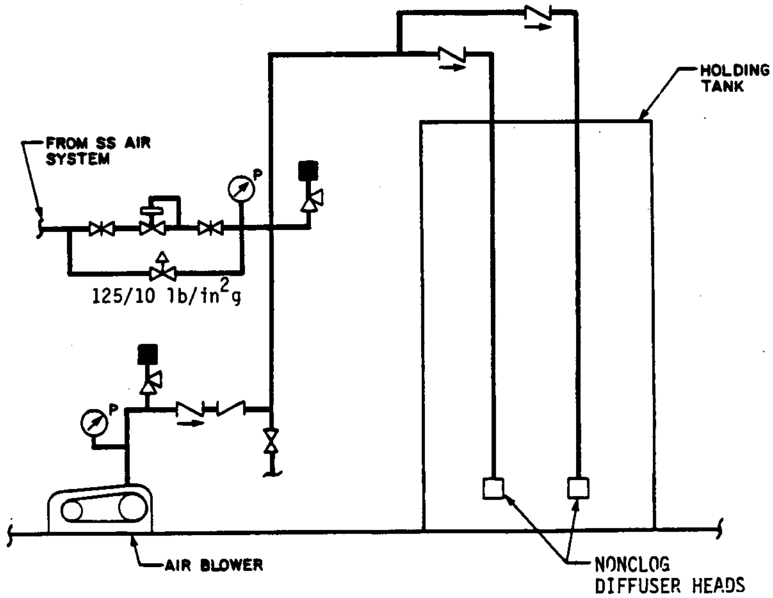


Figure 551-2-34 Typical (Independent) Sewage CHT Aeration System Diagram

551-2.5.5.2 Air diffusers are located in one or more air headers located on the bottom of the tank. The headers are designed so that the pressure drop across any individual header does not exceed 1/10 of the pressure drop across any individual diffuser in that header. Airflow to each diffuser is between 6 and 10 scfm. Headers are located in the same horizontal plane as close to the tank bottom as possible, but at least 2-1/2 inches from any tank surface. Air diffusers are suitable for service in a marine environment and are resistant to clogging. Diffusers prevent backflow of sewage into the aeration piping when the aeration system is inactivated.

551-2.5.5.3 Air diffusers are arranged in one of the following two configurations. If the tank can be designed with one tank wall having a width-to-depth ratio of 0.6 when full, then only a single header is required. The header is run perpendicular to this wall, on the low side of the sloping bottom, and as close to the adjacent wall as possible. In this configuration, diffusers are no further apart than 2 feet nor closer together than 6 inches. The other acceptable diffuser configuration is a grid layout. In this configuration, the CHT tank bottom is divided into a grid of equal and identical rectangular areas. One diffuser is located in the geometric center of each rectangular area. Diffusers are not located more than 3 feet apart in this configuration.

551-2.5.6 AIR DEBALLASTING SYSTEM. Surface ships utilizing an air blow system for deballasting include LSD, LPD, and LHA. A typical air blow deballast system consists of an air main loop from which branch lines supply air to ballast tank, remote-operated blow valves (as shown in Figure 551-2-35). Cross connection and isolating valves are provided in the loop main to enhance reliability of the system.

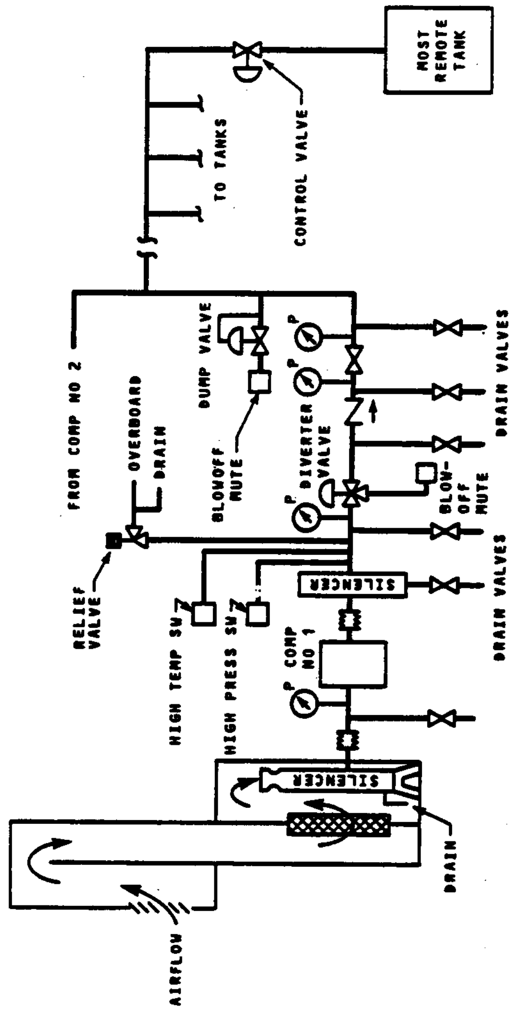


Figure 551-2-35 Air Blow Deballast System Diagram

551-2.5.6.1 The air main is supplied by several rotary-type air compressors for increased reliability of air supply. Compressor unit-capacities vary from 1,400 to 2,200 scfm and are set for a normal discharge pressure of 12 to 22 lb/in^2 depending on the type of ship. Intake air is supplied to the compressors by way of an air inlet filter and silencer with necessary provisions to minimize the possibility of water entrainment. Each compressor is provided, in the following order, with a discharge silencer, a diverter valve leading alternatively to a blowoff line fitted with muffler or to the air main, and a check valve and isolation valve upstream of the connection to the air main. A relief valve and appropriate local and remote-reading instrumentation are provided.

551-2.5.6.2 The diverter valve and blow-off line permits starting the compressor without load. A hydraulically operated unloading valve is also provided for each deballasting compressor on LHA's. Upon starting each compressor under a no-load condition, air is discharged to the atmosphere through the compressor unloader valve. An 8 ± 2 second time delay relay in the compressor control circuit inhibits closure control of the unloader valve until the compressor attains normal speed. Earlier ships such as LSD-36 through LSD-40 and LPD-4 through LPD-15 were not provided with unloading valves for the deballasting compressors. However, it should be noted that when deballasting, compressors start under unloaded or light load conditions, since the 10-inch deballast mains are depressurized and initial pressure required for deballasting is low (approximately 5 lb/in^2).

551-2.5.6.3 The isolation valve permits deballasting with as few compressors as required. Generally, the controls provide for local starting and local remote shutdown of the compressors. At each clean ballast tank fitted for air blow deballasting, compressed air is supplied by way of a motor-operated air blow valve. A motor-operated tank vent valve discharging to a vent line is provided. The vent and air blow valves are usually interlocked mechanically, acting as a unit so that the vent valve is closed when the air blow valve is open and vice-versa.

551-2.5.7 LP OXYGEN-NITROGEN (O_2 N_2) PRODUCER AIR SUPPLY SYSTEMS. Air is normally supplied to each LP O_2 N_2 producer by way of a dedicated centrifugal LP air compressor with an airflow capacity of not less than 1,750 scfm at 90 lb/in^2 . However, an emergency air supply is provided by SHIPALT, as required, to each LP O_2 N_2 producer from the vital air main of the ship service air system. In turn, the piping is arranged to allow the O_2 N_2 producer air compressor to serve as emergency supply to the ship service air system. If more than one O_2 N_2 producer plant is installed, the supplying air compressors discharge to a common header. In this case, isolation valves are installed in the cross connections from the ship service air system and the O_2 N_2 producer plants.

551-2.6 AIR FLASKS

551-2.6.1 RECERTIFICATION. Refer to paragraph 551-1.14.1.

551-2.6.2 INSPECTION. Refer to paragraph 551-1.14.2.

551-2.6.3 CLEANING. Refer to paragraph 551-1.14.3.

551-2.7 AIR SYSTEM

551-2.7.1 TESTS. Refer to paragraph 551-1.16.1.

551-2.7.1.1 Hydrostatic Pressure Test. If the work or repair done on the system violated the pressure boundary integrity of the system, perform a hydrostatic pressure test in accordance with the following or alternative testing as described in NSTM Chapter 505.

1. Disconnect all pertinent flasks, instruments, and equipment that might be damaged by the testing medium.
2. Subject all portions of the violated pressure boundary to the required hydrostatic pressure and hold for the specified time.
3. Upon satisfactory completion of the hydrostatic pressure test, drain out the test medium, blow out all remaining moisture, reconnect all instruments and equipment, and reconnect the flasks.

NOTE

Before flasks are reinstalled, clean and paint ship structure adjacent to the flasks.

551-2.7.1.2 Tightness Test. After air flasks are installed and connected to the piping, test all affected portions of the air system for air tightness according to paragraphs 551-1.16.1.2 or 551-1.16.1.3.

551-2.7.2 AIR SYSTEM INSPECTION (IN-SERVICE SHIPS). Refer to paragraph 551-1.16.2.

551-2.7.3 AIR SYSTEM CLEANING (IN-SERVICE SHIPS). Refer to paragraph 551-1.16.3.

551-2.7.4 AIR COMPRESSOR COMPLEX CLEANING. Refer to paragraph 551-1.17.2.

551-2.7.5 PIPING SYMBOL LIST. Refer to Figure 551-2-36 .

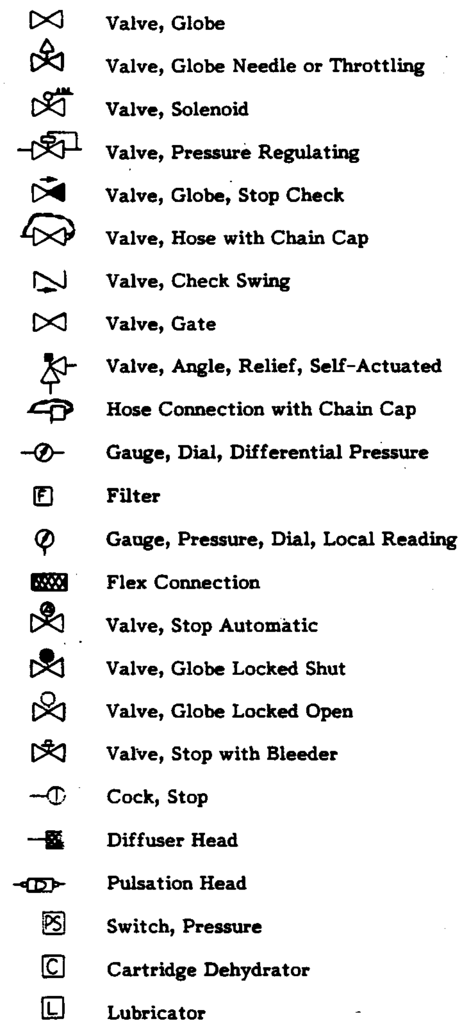


Figure 551-2-36 Piping Symbol List

SECTION 3.

SUBMARINES

551-3.1 HIGH-PRESSURE (HP) AIR PLANTS AND SYSTEMS

551-3-1.1 The service requirements on HP air compressors have risen steadily both in operating pressure and time. This increase is natural since the amount of air storage required has increased with the size of submarines. While the space occupied by HP air flasks for a given number of standard cubic feet of air capacity has been reduced by increasing the nominal operating system pressure, the overall required space increased. A 4,500 lb/in^2 HP air plant and system (earlier submarines had a 3,000 lb/in^2 air plant and system) consisting of HP compressors, moisture separators, oil/particulate filters, dehydrators, air banks, external air charging connection, and a piping distribution system of headers and mains with gauges, assorted valves, and pressure controls, provide compressed air on demand (see Figure 551-3-1 and Figure 551-3-2).

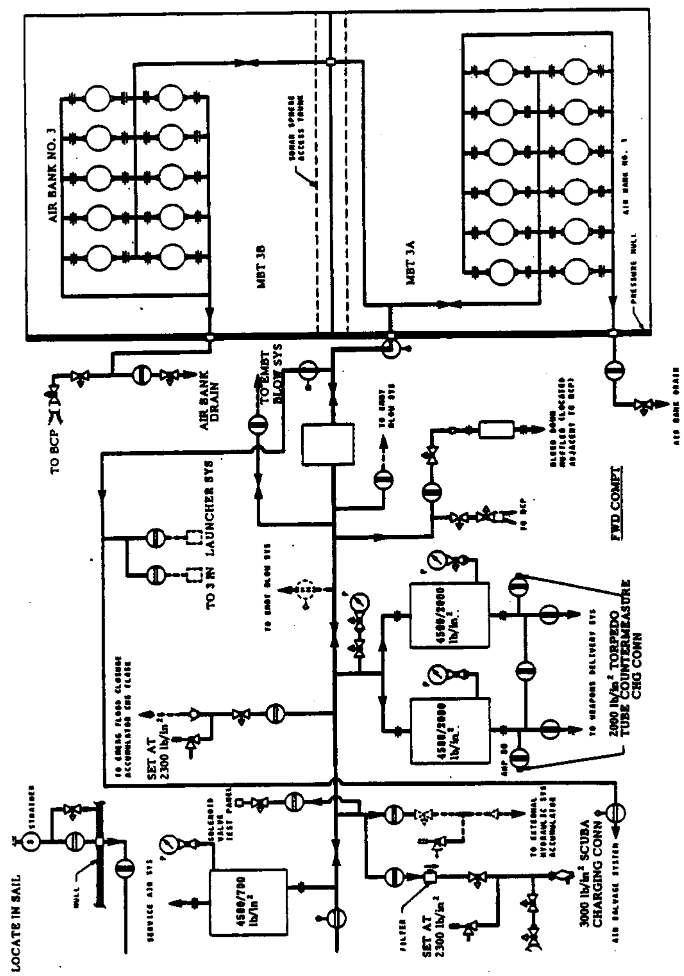


Figure 551-3-1 HP Air System (Fwd) SSN-688 Class

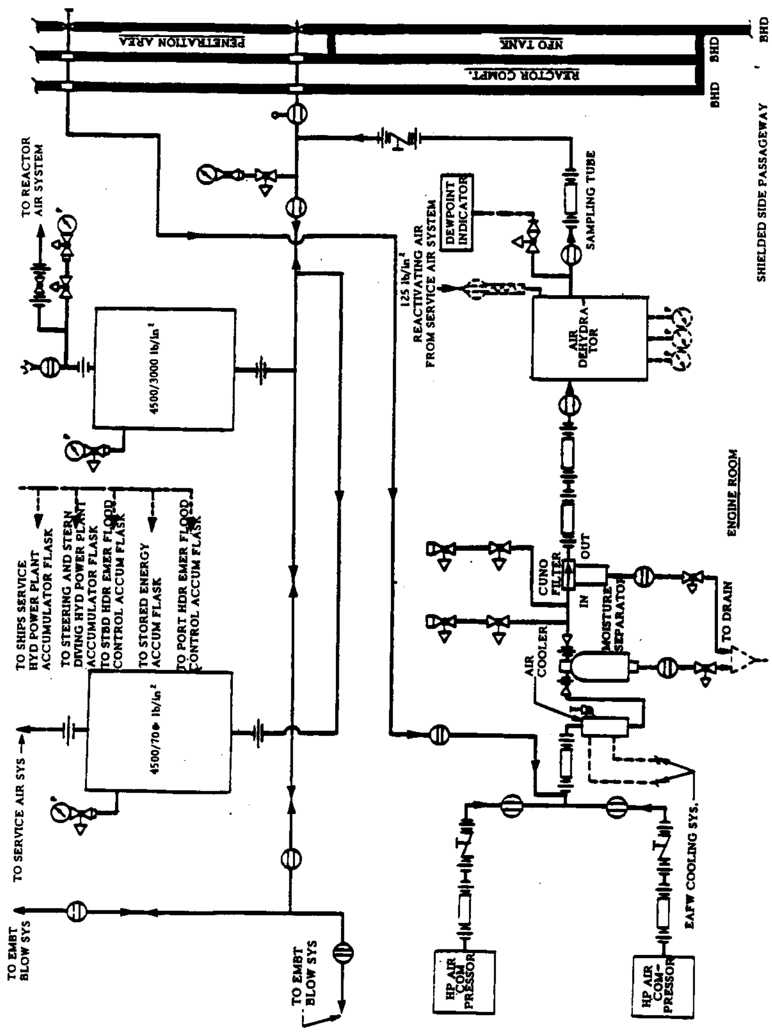


Figure 551-3-2 HP Air System (Aft) SSN-688 Class

551-3.2 AIR BANKS

551-3.2.1 INSTALLATION. HP air flasks, located either inboard or outboard of the pressure hull and in the main ballast tanks and installed in clusters of various sizes and shapes (straight cylindrical, and curved banana-like cylinders with belled ends and female-threaded necks), form the ship's air banks. Each double-ended flask in an air bank has the air inlet and outlet connection at the top end and drain connection on the bottom end. The top connection is a standard union assembly, generally according to NAVSEA dwg 810-1385884, provided with some means to prevent backing off. The drain end of the flask is generally fitted with a 1/4-inch nominal pipe size drain pipe secured to the flask by a union assembly.

551-3.2.1.1 The top inlet/outlet piping of each flask in an air bank located outboard of the pressure hull is manifolded together and led inboard of the pressure hull through a single hull penetration. An air bank hull stop valve is installed in the inboard piping at this penetration so that each air bank located outboard of the pressure hull has an inboard hull stop valve.

551-3.2.1.2 The drain piping at each flask in an air bank located outboard of the pressure hull is also manifolded together and led inboard of the pressure hull through a single hull penetration. A cutout valve and a needle valve arrangement are installed in the inboard drain piping at this hull penetration. Where these drain valves are considered inaccessible, extension rods are installed for their operation.

551-3.2.1.3 Each flask in an air bank is installed in a vertical or near-vertical position. The near-vertical position is defined as any position from the true vertical which permits complete drainage, with the ship on even keel, without extending the drain line into the flask. Flasks are installed to clear the pressure hull and tank plating, and the surrounding space is kept void. If the flask installation renders the surrounding tank plating and pressure hull inaccessible, provisions are made to facilitate their removal.

551-3.2.1.4 All ships have several HP air banks. Generally, only one of these HP air banks (TRIDENT class has two) is designated as the ship's HP service air bank. The remaining air banks form a critical part of the Emergency Main Ballast Tank (EMBT) blow system and are dedicated and normally isolated for that specific purpose. The ship's HP service air bank and each of the ship's EMBT blow system air banks have a valved interface with the ship's HP service air main. Local gauges, or remote indicators installed at the Ballast Control Panel (BCP), indicate air pressure in each air bank. The pressure sensing points are located in the air bank drain lines.

551-3.2.2 CHARGING. The three modes of charging submarine air banks are as follows:

1. Charging (surfaced)
2. Charging (submerged)
3. Charging (external source).

551-3.2.2.1 Surfaced. All of the ship's HP air banks during normal operations are charged from the ship's own two, sometimes three, High-Pressure Air Compressors (HPAC). While surfaced, and before any normal submergence, all of the ship's HP air banks should be topped-off to a nominal operating pressure of 4,500 lb/in^2 by the HPAC's taking suction on the ambient space, causing weather air to enter the ship's atmosphere by way of open trunk hatches.

551-3.2.2.2 Submerged. During submerged operations, external air is not available and the HPAC's generally are not running. Hence, all air evolutions which require a demand beyond the capability of the Low-Pressure Air Compressor (LPAC), if one is installed, use air supplied from the ship's HP service air bank. All external air evolutions performed while submerged, deplete the ship's total air supply which can only be reimbursed with external weather air while surfaced. All internal air evolutions performed while submerged, which require air from the ship's HP service air bank, cause the ship's atmospheric (ambient) air pressure to rise. The operation to control this rise in the ship's atmospheric air pressure is referred to as pump-down. The HPAC's are manually started to pump-down the ship's atmosphere so as to return the air to the HP service air bank from where it came, and the HPAC's are stopped only after the ship's atmospheric pressure drops to normal. If the ship's total air supply has not been depleted during a submerged operation, that is, external air evolutions and leakage were held to a minimum, the pump-down operation should return the ship's atmospheric pressure and the ship's HP service air bank pressure back to their original respective values.

551-3.2.2.3 External Source. The ship's HP air banks may also be charged from a source external of the pressure hull. Most external HP air connections are installed in the sail area. The outboard piping consists of a hose connection, check valve, strainer, hull valve, and the pressure hull penetration, in that order. A bleed-off valve is installed between the hull valve and the strainer to permit purging the external piping immediately before charging, and bleeding down the piping before disconnecting the air charging hose. Inboard piping has a hull backup valve installed at the hull penetration. Piping downstream of the hull backup valve connects into the ship's HP air system at a point upstream of the moisture separator flask in the compressor discharge at the HP air compressor complex. This point of connection ensures that HP air obtained from an external source can at least be processed by the equipment installed in the ship's own HP air compressor complex. External air charging bypassing the submarine's own air processing equipment should be according to the requirements of paragraph 551-1.15.4.

551-3.3 HP SERVICE AIR MAIN

551-3.3.1 OVERVIEW. The HP service air main extends fwd and aft throughout the ship. This air main serves as a supply source for all of the ship's compressed air demands (exclusive of the EMBT blow system) above 125 lb/in^2 . On ships that do not have an LPAC installed, this HP air main also provides the 125 lb/in^2 and below air demands. On ships that do have an LPAC installed, this air main supplements all LP air demands in excess of LPAC capacity.

551-3.3.2 AIR SOURCE. The air main is continuously supplied from the ship's HP service air bank through a normally-open solenoid control valve remotely actuated from the BCP. As compressed air is used, both the air bank pressure and the air main pressure are reduced to a lower valve. Large usage of compressed air results in a large reduction in air bank pressure which indicates the need to commence the compressor pump-down operation and return the excess air in the ship's atmosphere back to the ship's HP service air bank. This cyclic pump-down operation may be necessary as often as two to three times daily when usage and leakage of compressed air becomes excessive.

551-3.3.3 UPSTREAM AIR MAIN INTERFACES. In addition to the HP external air charging connection (paragraph 551-3.2.2.3), the upstream HP service air main interfaces include the HPAC complex, the HP service air bank, and the HP EMBT system. These interfaces are described in the following paragraphs.

551-3.3.3.1 HPAC Complex. Most SSN submarines have two HP air compressors installed, while SSBN submarines have three HP air compressors installed. The immediate compressor discharge piping generally consists of a relief valve, pressure gauge, over-pressurization switch, check valve, and stop valve, installed in that order, when these components have not been incorporated in the compressor. A moisture separator flask and a cartridge-type oil/particulate removal filter are installed, in that order, downstream of the stop valve in the compressor discharge as close as practicable to the compressor served. Both the separator flask drain line and the filter drain line are provided with a cutout valve and a needle valve. An instruction plate at the filter requires that the filter element be changed after each 200 hours of operation of the compressor or more often if experience so indicates.

551-3.3.3.1.1 To provide dry air, a dehydrator is installed in the compressor discharge piping downstream of the cartridge-type oil/particulate filter. The installed capacity of dehydrators is compatible with the installed compressor complex capacity; for example, if the output of two compressors can be directed to discharge into a single dehydrator, then the dehydrator capacity is rated for the combined output of both compressors. Most ship installations have a bypass cartridge dehydrator which can provide effluent air as required for a minimum of 4 hours when operating at maximum inlet temperature and minimum operating pressure.

551-3.3.3.1.2 Suitable isolation valves are installed to permit emergency air supply through the bypass dehydrator and to the system while the regular dehydrator is out of service and isolated for maintenance. Hence, during any HPAC operation, if the dewpoint indicator provided to sample/monitor the dehydrator performance indicates the quality of the effluent air as unacceptable, the foregoing capability provided by the bypass feature and the isolating valves should be put to use. The connection for using the dewpoint indicating instrument is located immediately downstream of the dehydrator. The combined output of all the HP air processing components in the ship's HPAC complex is directed and connected to the ship's HP service air main.

551-3.3.3.2 Ship's HP Service Air Bank. Filter and filter isolation valves are provided on both sides of the solenoid operated cutout valve installed in the piping connecting the air main to this air bank.

551-3.3.3.3 HP EMBT Blow System. See paragraph 551-3.4.

551-3.3.4 DOWNSTREAM AIR MAIN INTERFACES. The downstream HP service air main interfaces are described in the following paragraphs.

551-3.3.4.1 Self Contained Underwater Breathing Apparatus Charging Connection. This connection provides Self Contained Underwater Breathing Apparatus (SCUBA) charging air by way of a pressure reducing valve, stop valve, needle valve, relief valve, pressure gauge, special filter, and an automatic shutoff valve. A safety disconnect bleed feature is provided as part of the automatic shutoff valve or separately downstream of the valve.

551-3.3.4.2 Signal Ejector Impulse Flask Charging. A connection is provided to charge the signal ejector impulse flask by way of a pressure reducing station.

551-3.3.4.3 Torpedo Tube Impulse Flask Charging. A charging facility is provided to charge these impulse flasks by way of pressure reducing stations.

551-3.3.4.4 Countermeasure System Charging. A connection, taking its compressed air source from the downstream side of the torpedo impulse flask charging pressure reducing station, supplies compressed air to the countermeasure system charging by way of a ball valve, and a hose connection with an automatic cutoff feature. The system piping and valve configuration permit securing the compressed air to the torpedo impulse flask and firing valves without securing the countermeasure compressed air supply.

551-3.3.4.5 Launcher Firing System. A service connection provides compressed air to both 3-inch launcher firing systems.

551-3.3.4.6 Missile Thrust Vector Control. On SSBN ships, a service connection provides compressed air to the Thrust Vector Control (TVC) header by way of a pressure reducing station.

551-3.3.4.7 Normal HP Main Ballast Tank Blow System. A normal HP Main Ballast Tank (MBT) blow system is installed on earlier ships (before SSN-688 class). This system was retained on these ships even after the installation of an EMBT HP blow system. The normal HP MBT blow capability is provided through two normally-shut solenoid control valves, one serving the fwd group (port and starboard quadrants) of MBT's, and the other serving the aft group (port and starboard) of MBT's. Both the fwd and the aft normal HP MBT blow piping take their HP air supply from the HP service air main which, in turn, is supplied by the HP service air bank. The fwd normal HP MBT blow piping delivers the normal HP blow air by way of the fwd normal HP blow solenoid control valve and a check valve at the point immediately upstream of the tee connection into the fwd HP EMBT blow port and starboard cross-connect piping. The normal HP MBT blow piping aft has a similar configuration into the aft HP EMBT blow port and starboard cross-connect piping.

551-3.3.4.8 List Control. List control on earlier ships is generally provided by the Low Pressure (LP) MBT blow system (a surface deballasting capability). However, later SSBN ships, or earlier SSBN ships having only a simplified LP blow capability without the number of valves required to provide the list control feature, have an HP air list control capability.

551-3.3.4.8.1 The HP air list control capability provided on these ships is a modified normal HP MBT blow system. Four solenoid control isolation valves are added and installed, one in each port and starboard leg of the HP EMBT blow system port and starboard cross-connect piping such that each MBT quadrant is served by a solenoid control isolation valve. The list control capability is used in conjunction with the jettison firing of dud weapons. All list solenoid control valves have their actuation switches and position indicators located in the BCP area.

551-3.3.4.9 Compartment Pressurization. A compartment pressurization valve is installed on each holding bulkhead, and the valve is arranged for operation from each side of the bulkhead so that air pressure can be applied to that compartment or to the adjacent compartment. Compartment pressurization on earlier ships is accomplished with 700 lb/in^2 air pressure or lower. Later ships (SSN-688 class and after) utilize the ship's HP service air main as the air source supplied by the ship's HP service air bank.

551-3.3.4.9.1 The HP service air bank, on ships with an HP air compartment pressurization capability, is sized to fully support a flooded ship in a surface survival condition. This capability provides enough air to form the maximum trapped air bubble in a flooded engine room compartment which prevents flooding beyond the maximum allowable limits of a surface survival condition. The use of HP air, in place of lower pressure air, increases the rate of pressurization and therefore, the effectiveness of this surface survival support capability.

551-3.3.4.9.2 The sooner the compartment pressurization capability is initiated, once the ship has initiated an EMBT blow evolution due to compartment flooding at depth, the more effective its support becomes. Under certain casualty conditions, such as flooding occurring at a high point in the forward portion of the engine room compartment and stern down, compartment pressurization by itself serves no purpose since the entrapment of an air bubble is not possible unless the point of casualty can be effectively sealed off.

551-3.3.4.10 Missile Gas Tactical Backup and Onboard Training. The original missile systems installed on SSBN ships utilized HP air for the launching of missiles. Air flasks, clustered into missile launching air banks, were charged from the HP air compressor complex by way of the HP service air main. As the original missile weapons were replaced by the new missile weapons during the POLARIS and POSEIDON conversions, the missile launching system went from air flasks to gas generators.

551-3.3.4.10.1 The latest missile gas systems utilize nitrogen gas for missile tube pressurization and bias control functions. The gas is limited in quantity to the capacity of the HP missile nitrogen banks. To support this limited quantity of stored onboard nitrogen, an HP air supply taken from the HP service air main connects into the missile gas system as a tactical backup to perform the missile tube pressurization and bias control functions should the nitrogen become depleted. Air is also used for training purposes for a missile launch scenario demonstration.

551-3.3.4.11 Reactor HP Air. The HP service air main supplies HP air for reactor services by way of a separate branch supply. This separate branch ensures that the HP service air bank is readily available to provide reactor air services.

551-3.3.4.12 Hydraulic Accumulator Flask Charging. The ship's hydraulic accumulator air flasks are provided with an HP air charging capability by way of the HP service air main.

551-3.3.4.13 Ship's Service Air System Supply. The HP service air main supplies all other ship's service air pressure demands through two 4,500/700 lb/in^2 air pressure reducing stations, one located in the fwd compartment and the other in the aft compartment (TRIDENT also has a third amidships). Each of these 4,500/700 lb/in^2 air pressure reducing stations connects to the ship's 700 lb/in^2 services air main, which extends forward and aft, to supply all 700 lb/in^2 services and, through a system of other air pressure reducing stations and air mains, the other lower air pressure demands.

551-3.4 HP EMBT BLOW SYSTEM

551-3.4.1 CAPABILITY. The HP EMBT blow system should provide a minimum change in pitch angle of the ship as it ascends to the surface if the system is actuated at test depth under a no flooding condition at a 5-knot speed. The system as installed has the capability to recover the ship from a flooding casualty under the following conditions:

a. A single pipe rupture which would result in flooding equivalent to a 4-inch diameter hole in the hull having a coefficient of discharge equal to one

b. Ship at test depth, neutral buoyancy, and zero trim at time of casualty

c. Flooding occurs in the engine room

d. Air bank pressure in all air banks serving the emergency blow service is no more than 200 lb/in^2 below the nominal operating system pressure at the time of casualty

e. Control surfaces on zero at time of casualty and remain on zero during recovery evolution

f. Ship speed 5 knots immediately before casualty occurs

g. Propulsive power lost immediately after casualty occurs

h. Emergency ballast tank blow initiated 15 seconds after casualty occurs

i. Flooding secured 90 seconds after casualty occurs

j. No part of the ship exceeds collapse depth during recovery evolution

k. Ship considered surfaced when any part of pressure hull broaches the surface.

551-3.4.2 CONFIGURATION. The ship's MBT's are basically located and grouped into quadrants, such as fwd port, fwd starboard, aft port, and aft starboard (see Figure 551-3-3 and Figure 551-3-4). To keep the EMBT blow path short and direct and the number of components to a minimum, the EMBT blow system is divided into matching and comparable quadrants, generally consisting of:

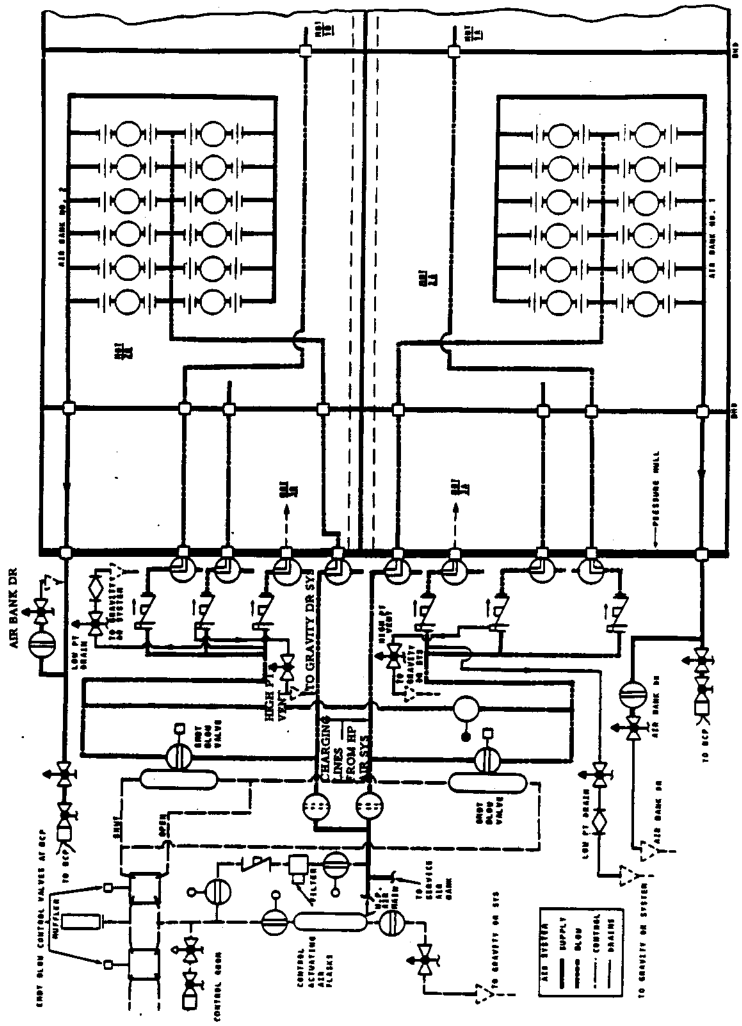


Figure 551-3-3 EMBT Blow System (Fwd) SSN-688 Class

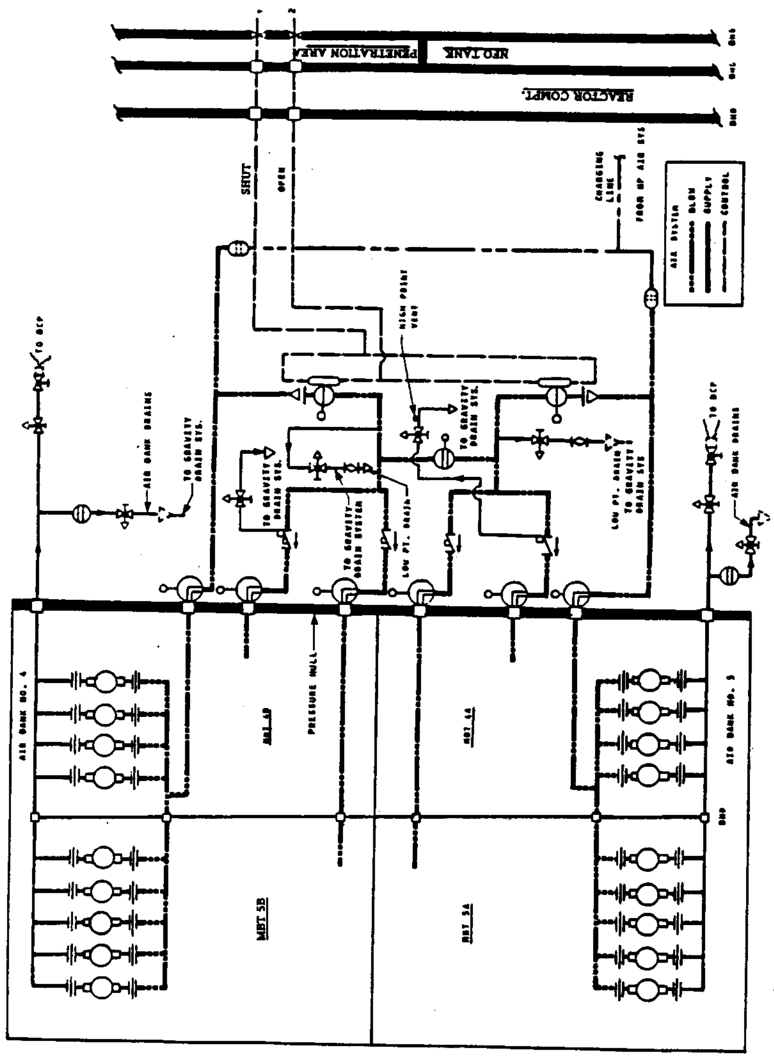


Figure 551-3-4 EMBT Blow System (Aft) SSN-688 Class

a. An HP EMBT air bank

b. An air bank piping hull penetration

c. An air bank hull stop valve

d. An EMBT blow valve

e. Branch piping downstream of EMBT blow valve to each MBT in a quadrant consisting of:
   1 A combined vent-check valve to each MBT
   2 An angle MBT hull stop valve to each MBT
   3 An air blow piping MBT hull penetration at the upper portion of each MBT
   4 A valved port-to-starboard cross-connection joining the port and starboard EMBT blow quadrants, each at a point downstream of its EMBT blow valve, but upstream of the branch piping to each MBT quadrant
   5 A line, tapped off at the low point of the blow piping between the vent-check valve and the EMBT blow valve, sloped to trap and drain water to an automatic drain valve
   6 An isolation valve upstream of each automatic drain valve

7 A valved vent line, installed at each vent-check, but only one of which is opened to vent the EMBT blow quadrant

8 A valved (normally shut) interface between an EMBT blow system quadrant and the ship's service air main which provides isolated and independent EMBT blow system operation.

551-3.4.2.1 The system (exclusive of the actuating air) does not contain strainers, orifices, restrictions, or filters. Pipe covering or insulation is not installed on the portion of piping from the EMBT blow valve to the MBT hull stop valve in order to minimize the possibility of freeze-up during a blow operation. EMBT vent-check valves are normally installed in the horizontal pipe runs with the check housing oriented at least 10 degrees above the horizontal. The angle hull stop valves are soft seated and constructed so that all trim (seats and discs) can be replaced without removing the valve with welded end connections from the piping.

551-3.4.2.2 The individual angle MBT hull stop valves are provided so that in case of a casualty to any MBT, the valve for that tank can be shut to prevent escape of blow air when blowing other tanks. Non-galling material combinations are used for union-end components, and nut and thread piece of all union connections. Some means, such as tack welding, is provided to secure the nut portion of all union connections to prevent loosening of the joint by vibration. All drains, relief and vent piping, should be arranged to prevent spraying or leakage of seawater on equipment.

551-3.4.3 CONTROL AND ACTUATION. The EMBT blow valves are actuated by HP actuating air controlled by manually operated control valves located near the BCP. These control valves are positioned to permit rapid one-hand operation of the detented operating lever in the upward direction to open the EMBT blow valves. Once a control valve is manually operated, the actuating air system response time to fully open the EMBT blow valves is a maximum of 6 seconds.

551-3.4.3.1 One control valve is provided for control of two EMBT blow valves fwd (one in the fwd port quadrant and one in the fwd starboard quadrant), and one control valve for the control of two EMBT blow valves aft (one in the aft port quadrant and one in the aft starboard quadrant). This control concept divides the operation of the EMBT blow system into a fwd EMBT blow capability and an aft EMBT blow capability. Hence, the option to activate the fwd EMBT blow control valve only, the aft EMBT blow control valve only, or both control valves simultaneously exists and provides flexibility of operation. This control concept also eliminates the hazard of not blowing both port and starboard MBT quadrants simultaneously.

551-3.4.3.2 One or more flasks are provided to serve as an alternate source of compressed air in the EMBT blow actuating air system. The flask is charged from the HP service air main by way of a locked open stop valve, a filter without an automatic bypass feature, a check valve, and a locked open stop valve. The flask is provided with a locked open isolation valve and a double valved drain outlet. The volume of a flask is sufficient to provide four complete operating cycles of all EMBT blow valves.

551-3.4.3.3 A pressure gauge is installed in the all-welded EMBT blow actuating air system. The EMBT blow valves are operable with actuating air pressure as low as 1,000 lb/in^2 with pressure on the EMBT blow air bankside of the EMBT blow valve at the full nominal operating pressure of the EMBT blow system. An EMBT blow valve may be operated locally, with the manual override, regardless of its position as remotely controlled from the BCP. All EMBT blow valves fail in the as is position. Limit switches indicate the position of the EMBT blow valves at the BCP.

551-3.5 LP SERVICE AIR SYSTEM

551-3.5.1 OVERVIEW. The LP service air system is sized and arranged to supply all services at the pressures and flow rates up to the total demand of the services which are operated simultaneously. Air filters are provided to remove contaminants down to the smallest size necessary to protect the equipment served. Air supplied for services external to the pressure hull are taken from a higher pressure source than test depth pressure by way of a separate reducing valve to avoid the possible seawater flooding of any other air service inside the pressure hull.

551-3.5.2 DISTRIBUTION. All services are rendered by way of installed air mains (at various pressures) rather than by way of the older concept (pre-PERMIT SSN-594 class) of utilizing air distribution manifolds (see Figure 551-3-5, Figure 551-3-6 and Figure 551-3-7).

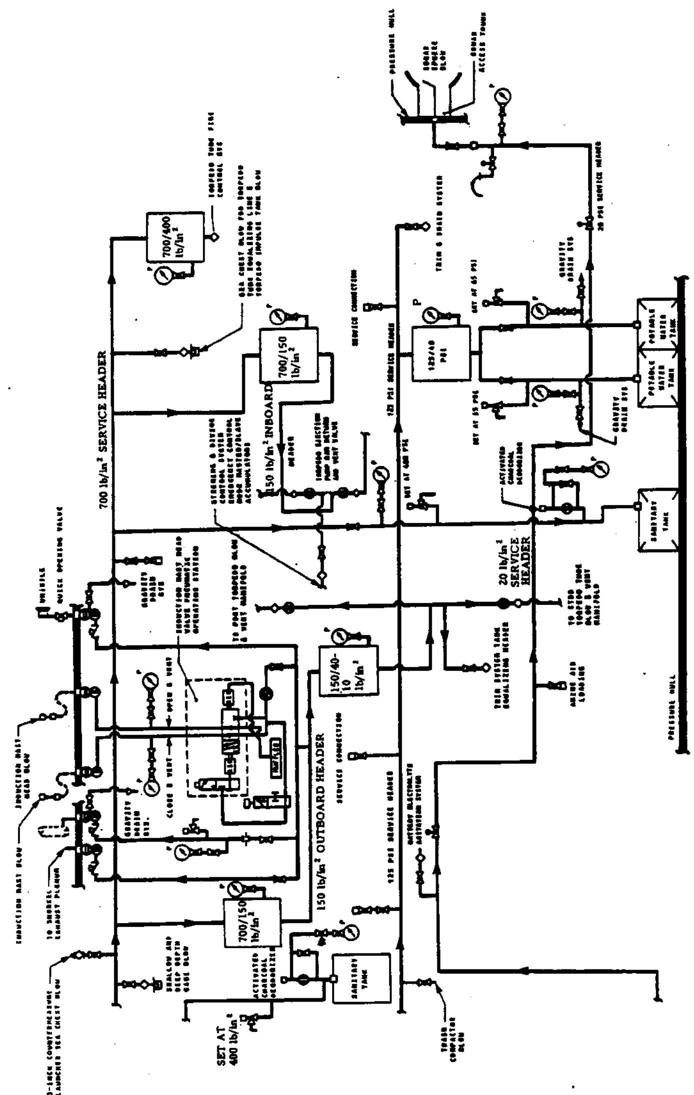


Figure 551-3-5 Service Air System (Fwd) SSN-688 Class

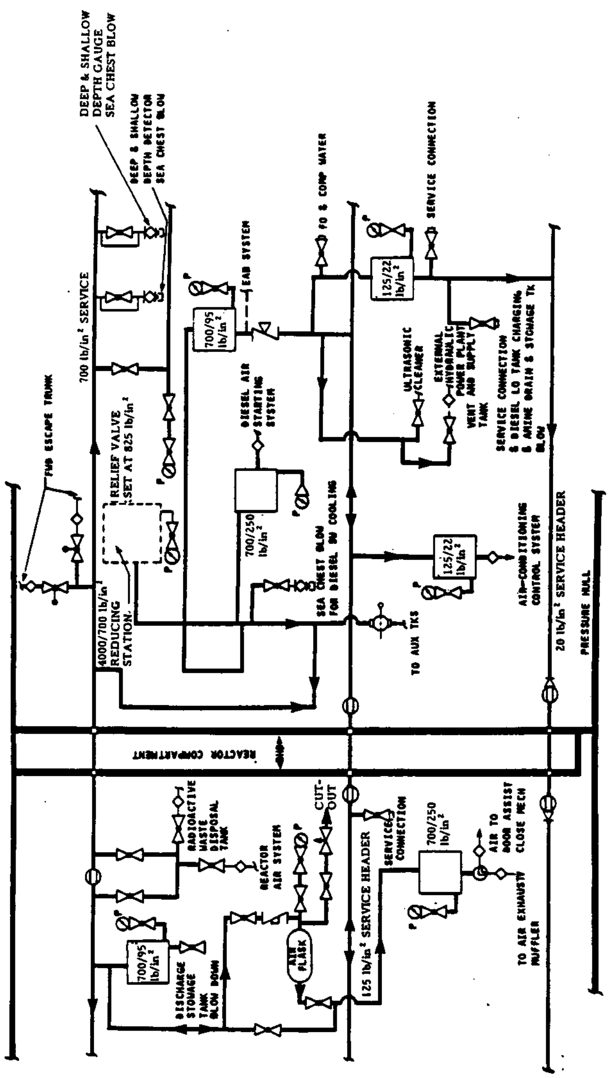


Figure 551-3-6 Service Air System (Midship) SSN-688 Class

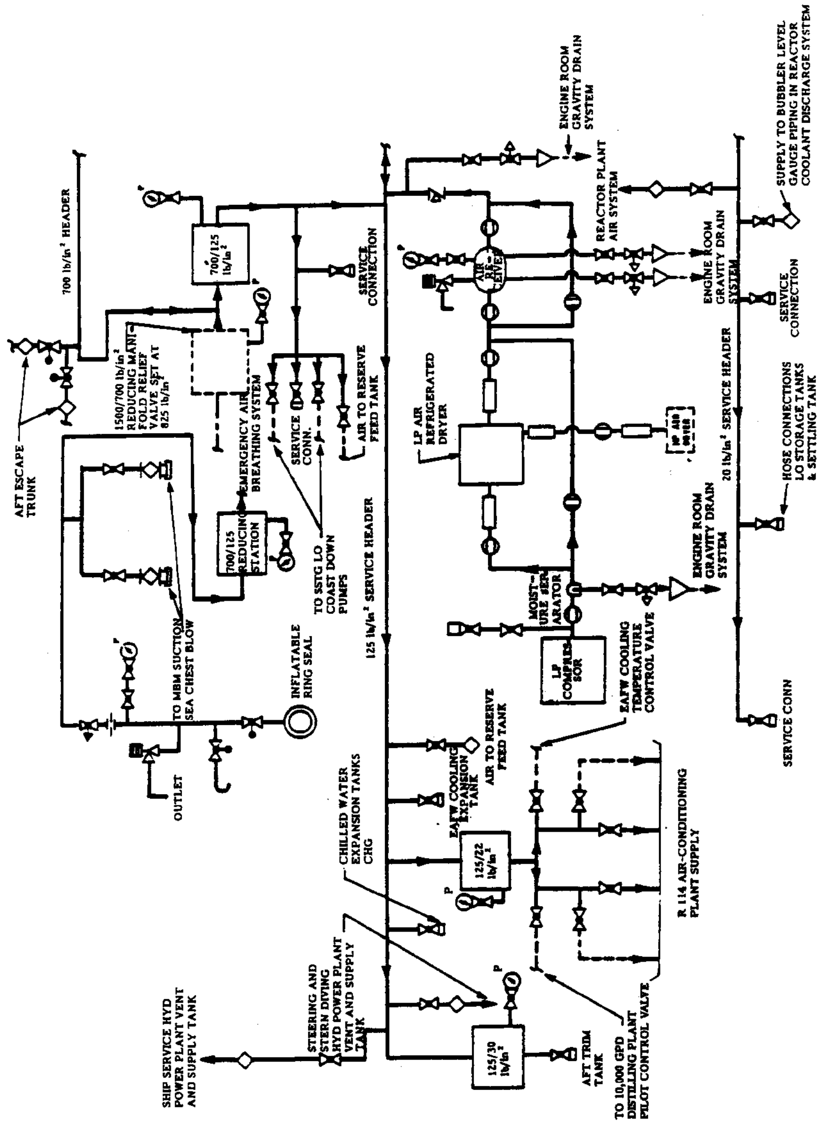


Figure 551-3-7 Service Air System (Aft) SSN-688 Class

551-3.5.3 THE 700 LB/IN^2 AIR MAIN. The 700 lb/in^2 service air main takes its supply from the 4,500 lb/in^2 HP air main by way of 4,500/700 lb/in^2 reducing stations. This service air main provides air services to:

a. Diesel engine air by way of a reducing station

b. Diesel exhaust mast blow

c. Reactor plant air service by way of a reducing station

d. 400 lb/in^2 torpedo firing air by way of a reducing station

e. Signal ejector or 3-inch launcher sea chest blow

f. Missile compensating by way of a reducing station

g. Deep and shallow depth gauge sea chest blow

h. Inflatable shaft ring seal

i. Shallow depth gauge blow
j. Deep and shallow depth detector sea chest blow
k. Hovering and depth control tanks
l. Hard sanitary tanks
m. Torpedo equalizing line sea chest blow
n. Torpedo impulse tank blow and impulse tank emergency overboard vent
o. Seawater sea chest blow
p. Emergency cooling heat exchanger blowdown
q. Service to compartment hose valves
r. Compartment salvage air valves for lower pressure salvage air systems
s. Missile gas sea sensing and under hatch equalization headers sea chest blow
t. Escape trunk air services
u. Both 150 lb/in^2 headers, 125 lb/in^2 air main, emergency breathing service, and 20 lb/in^2 air main.

551-3.5.4 THE 150 LB/IN^2 OUTBOARD HEADER. The 150 lb/in^2 outboard air header takes its supply from the 700 lb/in^2 service air main by way of a 700/150 lb/in^2 reducing station. This header provides air services to outboard (seawater) connected functions such as the torpedo tube blow and vent manifold, Water Round Torpedo (WRT) tank blow, snorkel head valve control, ship's whistle, induction mast blow, trim and drain equalization headers by way of a pressure reducing station, and bridge access trunk ventilation. This header should never be cross-connected to any other inboard service in order to prevent seawater contamination of inboard air services.

551-3.5.5 THE 150 LB/IN^2 INBOARD HEADER. The 150 lb/in^2 inboard air header takes its supply from the 700 lb/in^2 service air main by way of a 700/150 lb/in^2 reducing station. This header provides air services to the torpedo tube firing ram and any other inboard services requiring this pressure.

551-3.5.6 THE 125 LB/IN^2 SERVICE AIR MAIN. The 125 lb/in^2 service air main takes its source from the LPAC complex which is supplemented from the 700 lb/in^2 service air main by way of two pressure reducing stations, one located aft and one located fwd (TRIDENT class ships also have an external air charging connection to the 125 lb/in^2 air main). The 125 lb/in^2 service air main provides air services for:

a. Flushing water tank air loading
b. Potable water tank air loading
c. Chill water expansion tank air loading
d. External hydraulic vent and supply tank air loading
e. Compartment maintenance service air hose connections
f. HP air dehydrator purge
g. Ultrasonic cleaner
h. Oxygen generator
i. Ship's service turbine generator

j. Coast down pump air supply

k. Hydraulic power plant vent and supply tank

l. Trash disposal unit

m. Fuel and compensating system

n. Air-conditioning plant control air supply by way of a reducing station

o. Ventilation and air-conditioning control air supply by way of a reducing station

p. 100/20 lb/in^2 service air main.

551-3.5.7 EMERGENCY AIR BREATHING. The emergency air breathing service on ships before the SSN-688 class is an integral part of the air services provided by the ship's 125 lb/in^2 service air main (see Figure 551-3-8 and Figure 551-3-9). For these earlier ships, branch lines from this service air main provide emergency breathing air throughout the ship to serve the ship's entire personnel by way of special filters and manifolds. Manifolds, with sufficient number of outlets, are installed at each battle and normal watch station, in the wardroom, CPO lounge, on both sides of watertight doors, and in all main fore and aft passageways in support of the movement of damage control parties.

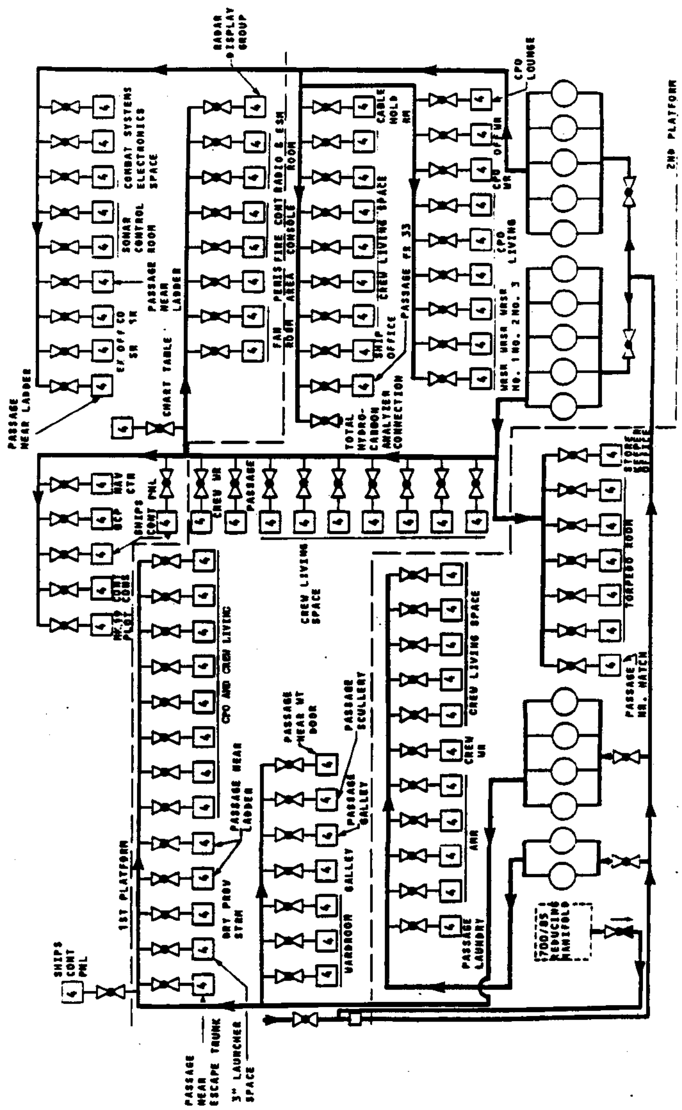


Figure 551-3-8 Emergency Air Breathing System (Fwd) SSN-688 Class

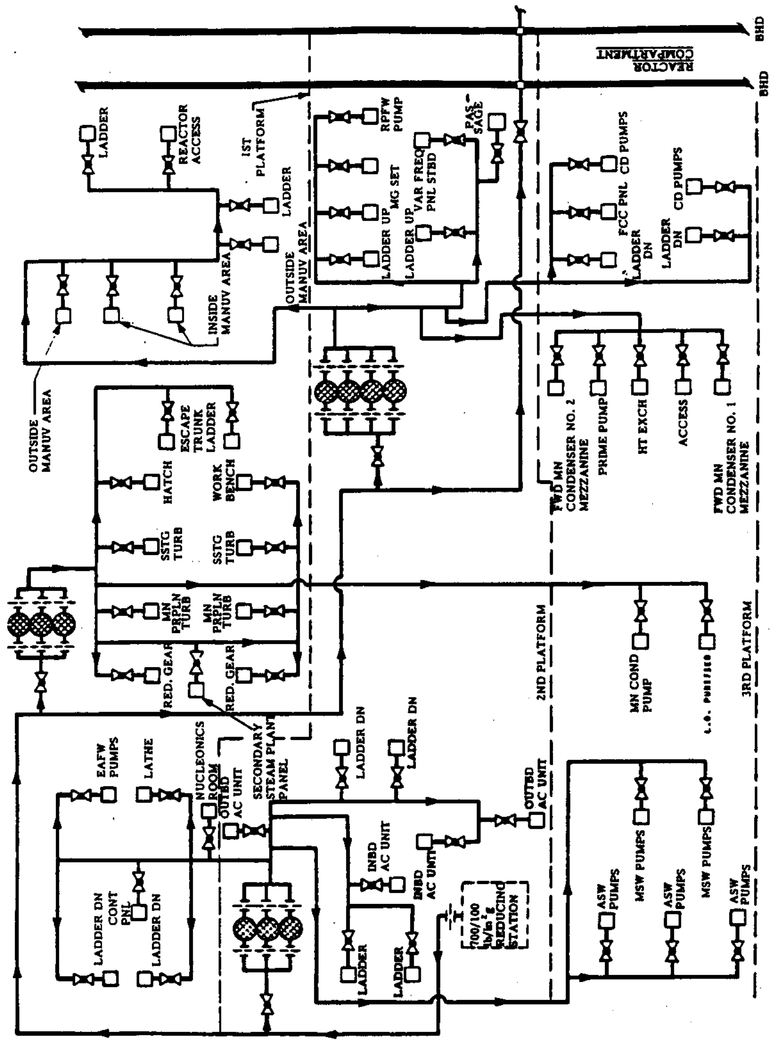


Figure 551-3-9 Emergency Air Breathing System (Aft) SSN-688 Class

551-3.5.7.1 The emergency air breathing service on ships commencing with the SSN-688 class is provided by a dedicated 100 lb/in^2 emergency air breathing service air main supplied from the 700 lb/in^2 service air main by way of two 700/100 lb/in^2 reducing stations, one located fwd and one located aft. As in earlier ships, emergency breathing air is distributed to the ship's entire personnel by way of special filters and manifolds located at the critical stations. The installation of a dedicated emergency air breathing service air main, divorcing this piping from all other ship service air piping (exclusive of its air source), simplifies cleaning procedures by limiting the amount of piping to be cleaned to breathing air standards.

551-3.5.8 THE 20 LB/IN^2 SERVICE AIR MAIN. The 20 lb/in^2 service air main takes its supply from the 125 lb/in^2 service air main by way of two 125/20 lb/in^2 reducing stations, one located fwd and the other located aft. The 20 lb/in^2 service air main provides service air to:

a. Diesel generator lube oil tank loading

b. Steam blanket reducing valve air loading

c. Amine storage drain air loading

d. Oxygen generator

e. Amine drain tank blow

f. Amine fill tank

g. Reserve feedwater tank blow

h. Sonar sphere blow

i. Fuel system tank blow

j. Ventilation of special torpedoes

k. Hovering system supply

l. Battery electrolyte agitation (see paragraph 551-3.5.13)

m. Lube oil stowage and settling tanks

n. Reactor plant services

o. Missile temperature control

p. Compartment maintenance hose connections.

551-3.5.9 ESCAPE TRUNK SERVICES. Air services for both the fwd and aft escape trunks are supplied from the 700 lb/in^2 air main (see Figure 551-3-10). Pressurization of an escape trunk can be accomplished in a maximum time of 18 + 2 seconds with the ship at the maximum working depth of the Steinke Hood escape appliance, and the escape trunk flooded to the design bubble line.

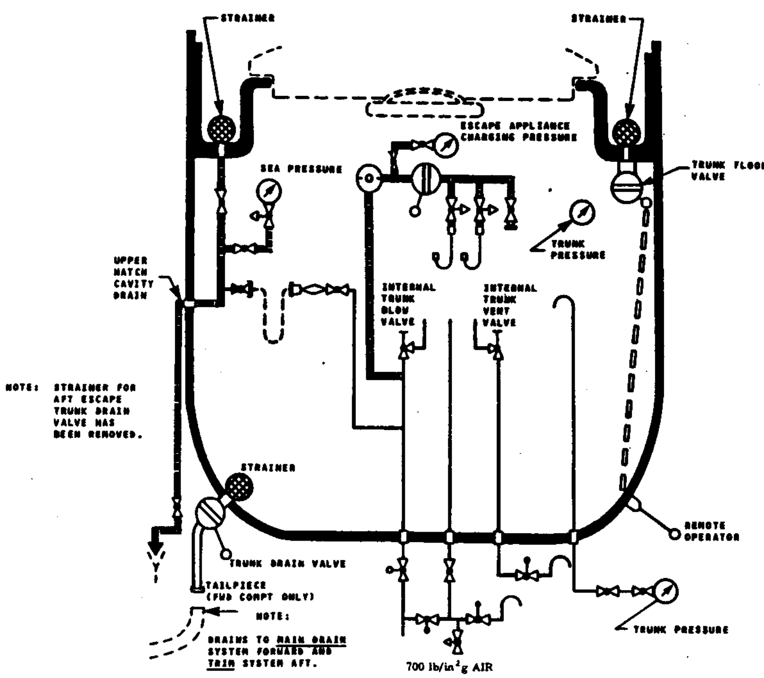


Figure 551-3-10 Escape Trunk System

551-3.5.9.1 The escape appliance charging manifold has at least two, but not more than four, hose outlet connections compatible with the Steinke Hood escape appliance connection. The escape appliance charging manifold has a stop valve for each hose outlet and a quick-acting master manifold blow valve. The manifold is supplied with compressed air by way of an adjustable reducing valve mounted in the trunk so that pressure on the manifold can be regulated to 100 lb/in^2 above trunk pressure.

551-3.5.9.2 The manifold has the capacity to deliver a quantity of air sufficient to charge four escape appliances simultaneously in 18 + 2 seconds at the escape appliance's maximum working depth. A diver's hose connection is provided inside the trunk, just downstream of the regulator in the escape appliance charging supply line, to supply air to the lightweight diving outfit.

551-3.5.10 SALVAGE AIR SERVICES. Salvage air services are provided that enable a diver to apply air pressure to each compartment, enable a diver to apply air to the HP air main, and enable the crew in any compartment to apply air pressure to that compartment and to the adjacent compartments (see Figure 551-3-11). To accomplish these functions, the salvage air services are divided into two parts described in the following paragraphs.

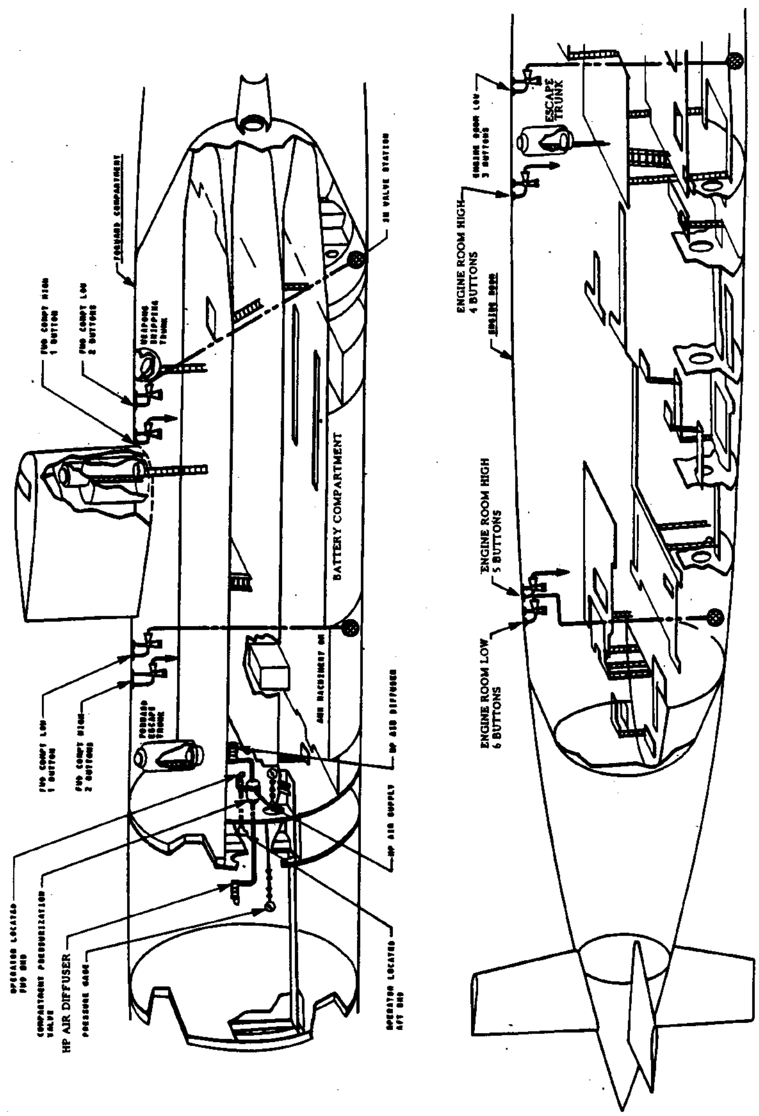


Figure 551-3-11 Salvage Air System

551-3.5.10.1 Compartment Diver's Air Connection. Each main compartment, except the reactor compartment, is provided with a minimum of two (one high and one low), four if necessary (two high and two low), diver's air connections installed flush with the outer hull as near the centerline as possible. Each diver compartment air connection is fitted with a quick disconnect-type cap and nipple. These fittings are NATO-approved and are as specified in Naval Sea Systems Command (NAVSEA) Submarine Safety Certification Manual. Piping between nipple and the diver's salvage air hull valve is welded. Each air connection is led inboard through the diver's salvage air valve installed in the pressure hull.

551-3.5.10.1.1 The diver's salvage air valves are operable from both inside and outside the pressure hull. Where necessary, in the double hull area, valve stem extensions are provided. Extension stems without handwheels terminate with squared ends adjacent to the air connection at the outer hull. A special salvage wrench/tool is used by the diver. The pronged end is used to remove the quick disconnect-type cap from the piping nipple, and the socket end is used to operate the salvage air hull valve. Marker plates are installed on the top of the outer hull at each diver's salvage air valve operating station and the HP air external charging connection, to enable the diver to identify the valve and at the diver's compartment air connections.

551-3.5.10.1.2 One low salvage air line in each compartment terminates at the low point of the compartment (when two low salvage air lines are installed, one low salvage air line terminates at the fwd low point and the other at the aft low point of the compartment) with the submarine on an even keel. Each low salvage line is provided with a strainer at the lower end and led in the most direct manner to its diver's salvage air hull valve. The diver's salvage air hull valve is located directly above the low salvage line terminals where practicable. The low salvage line may tie into a bilge suction line between the strainer and check valve in order to reach the low point. The high salvage line in each compartment is located so that it can be used to receive air and liquid food. The discharge of the valve is located to prevent seawater spray on equipment or cabinets.

551-3.5.10.1.3 The arrangement and configuration of the high and low salvage air lines in each compartment provides a means for dewatering a flooded compartment and for circulating ventilating air within that compartment during a salvage operation. The HP external air charging connection, specified in the HP air system herein, serves as the salvage air connection to the HP air system. Salvage and gagging wrenches are carried aboard for purposes of periodic operational checks. Wrenches for diver and salvage purposes should be carried aboard rescue ships.

551-3.5.10.2 Compartment Pressurization Air Supply Connections. The salvage air system on earlier ships provides a means for the crew in any compartment to apply air pressure to that compartment and the adjacent compartments by way of outlets having stop valves from the 700 lb/in^2 air main installed on the holding bulkheads. The air is supplied by way of compartment pressurization valves, installed on each holding bulkhead, which are arranged for operation from each side of the bulkhead so that air pressure can be applied to that compartment or to the adjacent compartment (for later ships, see paragraph 551-3.3.4.9).

551-3.5.11 LPAC COMPLEX. Before the SSN-685, ships did not have an LPAC specifically installed to provide an LP air supply (see Figure 551-3-12). Oxygen generator installations, equipped with pneumatically operated valves, were supplied with accompanying compressors rated at approximately 15 scfm at 85 lb/in^2 . The output of these small dedicated compressors, when not required for O2 generator valve operation, was directed to supplement the ship's other LP air demands.

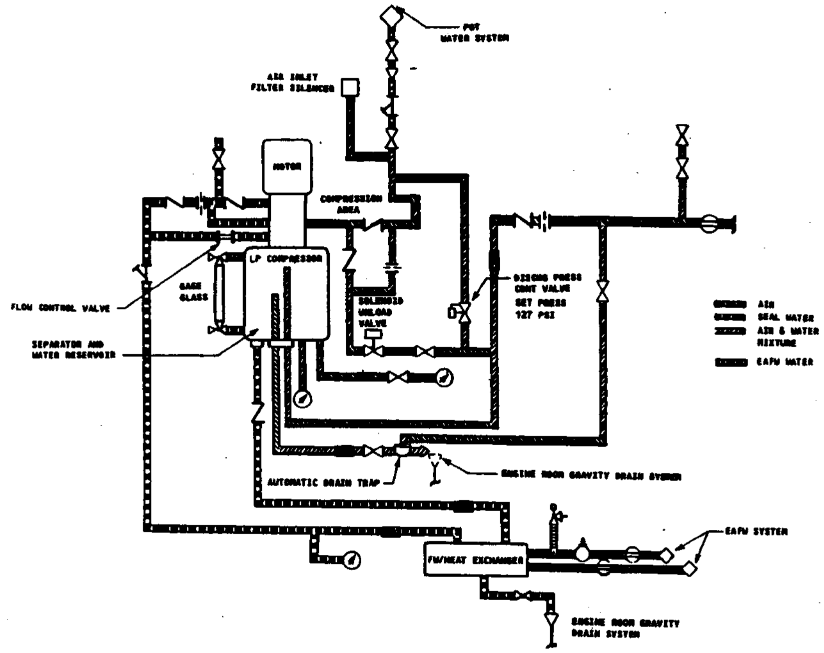


Figure 551-3-12 Service Air Compressor

551-3.5.11.1 An LPAC complex was installed on the SSN-685 during initial construction and on all subsequent new construction ships. Many previous ships have received an LPAC complex installation by way of Ship Alteration (SHIPALT).

551-3.5.11.2 The basic LPAC complex consists of a single LPAC rated at a minimum of 35 scfm when operating at a discharge pressure of 125 lb/in^2 . The compressor is suited for continuous duty and equipped with automatic controls for start-stop operation, and with bypass controls for continuous running. The compressor discharges to the 125 lb/in^2 service air main by way of a dehydrator and a receiver of sufficient capacity to permit start-stop compressor operation without excessive cycling of the compressor drive motor. Valves installed in the LPAC complex provide a means to isolate its discharge to the ship's 125 lb/in^2 service air main. When these valves are closed, all air demands on the 125 lb/in^2 service air main are supplied from the ship's 700 lb/in^2 service air main.

551-3.5.11.3 The LPAC may be secured remotely from the BCP. The LPAC is generally operated in the continuous running mode because of its relatively quiet operating features. When the LPAC is operating in the continuous running mode and the air demand falls below the LPAC's capacity, the excess air is unloaded through its automatic-dump feature (see Figure 551-3-12).

551-3.5.12 LP MBT SURFACE DEBALLAST BLOW SYSTEM. The LP surface deballast blow system is arranged for deballasting the MBT's with LP air while the ship is on or near the surface. On some ships, the system piping external to the pressure hull is provided with a backflood feature, but is still designed for a minimum external pressure equal to the design collapse depth so that it can withstand test depth pressure. On ships that do not have the back-flood feature installed, the piping external to the pressure hull should be designed to the special requirements for piping external to the pressure hull which is non-liquid filled (see Figure 551-3-13).

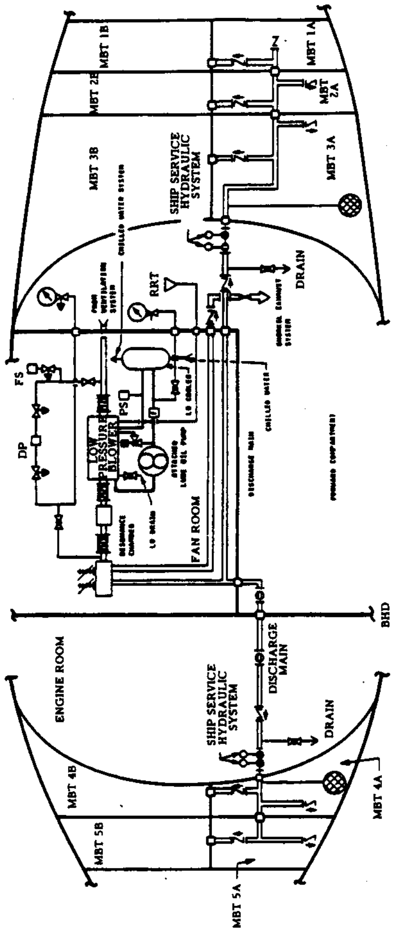


Figure 551-3-13 LP MBT Blow System SSN-688 Class

551-3.5.12.1 One, or more if necessary, motor-driven LP blower is installed to serve the LP MBT blow system. The blower delivers sufficient air to blow, in not more than 30 minutes, all but residual water from the MBT's upon emergence from a submerged run, and to meet the ventilation exhaust requirements. The blower is of the rotary positive-displacement type with intermeshing, gear-timed, non-contacting rotors. It is directly driven through a flexible coupling.

551-3.5.12.2 The blower requires no lubrication in the compression area and is provided with shaft seals between the rotors and bearing chambers to restrict outward air leakage and prevent oil flow into the compression areas. A forced-feed lubrication system including oil pump, oil filter, oil pressure control, and oil cooler is provided. The oil cooler is according to MIL-C-15730. The electric motor is according to MIL-M-17060. It is suitable both for driving the blower exclusively for ventilation (without ballast blowing) and for driving the blower for surface deballasting for the maximum required deballasting period.

551-3.5.12.3 The blower is provided with a relief valve in the air discharge line to prevent blower overloading and excessive internal temperature. The relief valve is sized to pass the full blower capacity and is set approximately 12 percent above the maximum required blower discharge pressure. Two relief valves are, at times, employed in place of a single valve to reduce overall valve size.

551-3.5.12.4 The blower shuts down automatically on low lube oil pressure, low air inlet pressure (suction pressure), and excessive differential air pressure between blower inlet and discharge. The low lube oil pressure shutdown device is capable of being bypassed during start-up for a period of approximately 15 seconds by a time delay relay. The high differential air pressure switch cutout setting is approximately 6 percent above the maximum required differential operating pressure (maximum required discharge pressure plus maximum permissible vacuum at inlet).

551-3.5.12.5 The automatic shutdown devices have adjustable setpoints. Automatic shutdown protection for low inlet pressure to the blower should not be bypassed during blower starting period. The necessary gauges are provided to assist in the control of the pressure at critical points in the system.

551-3.5.12.6 Some ships have the piping for the diesel overboard exhaust function integrated with the piping for the low pressure MBT surface deballasting/ ventilation overboard functions. In this case, the piping complex contains the required number of isolation valves, interlocks, and controls to ensure independent system operation for each specific functional requirement.

551-3.5.13 MAIN STORAGE BATTERY ELECTROLYTE AGITATION SYSTEM. An electrolyte agitation system is installed for each battery. The system is supplied with either a motor-driven fan or an LP compressor complete with controller, or the agitation air is taken from the 20 lb/in^2 air main. Suction for the fan or LP compressor is taken from the battery tanks by way of a cleanable, permanent type filter. Air from either source is supplied through filters (to remove oil and particulate contaminants), an airflow indicator, and a key-operated globe valve located outside but adjacent to the battery tank. The pressure is reduced as necessary by means of an orifice or a pressure-reducing valve. The system within the battery tank is arranged to provide unIform distribution of airflow to each battery cell without the need for additional adjustment devices except for an orifice located in the air supply line to each battery cell.

551-3.6 AIR SYSTEM

551-3.6.1 TESTS. Refer to paragraph 551-1.16.1.

551-3.6.1.1 Hydrostatic Pressure Test. If the work or repair done on the system violated the pressure boundary integrity of the system, such as hot work of fabrication, perform a hydrostatic pressure test in accordance with the following or alternative testing as described in NSTM Chapter 505.

1. Disconnect all pertinent flasks (ballast tank, torpedo impulse, and so on), instruments, and equipment that might be damaged by the testing medium.
2. Subject all portions of the violated pressure boundary to the required hydrostatic pressure and hold for the specified time (see NSTM Chapter 9880, Damage Control; Compartment Testing and Inspection).
3. Upon satisfactory completion of the hydrostatic pressure test, drain out the test medium, blow out all remaining moisture, thoroughly dry the system using nitrogen or clean dry air, reconnect all instruments and equipment, and reconnect the flasks.

NOTE

Before flasks are reinstalled, clean and paint ship structure adjacent to the flasks.

551-3.6.1.2 Pressure-Drop Test. After air flasks are installed and connected to the piping, test all affected portions of the air system for air tightness according to paragraph 551-1.16.1.2. The following systems are exempt from the pressure-drop test either because they are pressurized only intermittently to perform a specific function or because their multiple components make this pressure-drop test impractical.

a. Air-conditioning control air

b. Submarine HP MBT blow piping downstream of the blow valves

c. Torpedo firing and torpedo impulse air systems

d. Diesel starting air piping downstream of the starting valve

e. Emergency air breathing piping downstream of the station cutout valve.

551-3.6.1.2.1 In place of pressure-drop testing, charge the foregoing systems with air to the system nominal operating pressure and visually check (soap bubble) all joints for leaks. Correct all leaks and repeat the test as necessary to ensure that there are no leaks in the system.

551-3.6.1.3 Special Test. Some air systems are considered to be in special categories and are therefore tested according to the following:

a. LP MBT Blow Air Surface Deballasting System. This test applies only to the portion of this system that is installed exterior to the pressure hull and is located between the tank top check valve at each MBT, and the hull and hull backup valves at the pressure hull penetration. Even though this exterior portion of the system is designed to two different design criteria, depending on whether the piping remains void/empty or is back-flooded upon submergence, the required hydrostatic test pressure is to be 150 percent of the submarine’s deep submergence test depth held for at least 15 minutes.

b. Salvage Air System. Each diver’s compartment salvage air connection, installed flush with the outer hull and as near the ship’s centerline as possible, shall be hydrostatically pressure-tested to maintain pressure hull integrity. The pressure hull integrity area of each of these connections lies between the hull backup valve at the pressure hull penetration and the outer disconnect cap which is considered to be the hull valve. In installations that are located in the double hull area, this includes the air piping extension between the hull backup valve and the outer cap/hull valve. Each of the above pressure hull integrity areas are to be tested to a hydrostatic test pressure of 150 percent of the submarine’s deep submergence test depth held for the required time.

551-3.6.2 INSPECTION (IN-SERVICE SHIPS). Refer to paragraph 551-1.16.2.

551-3.6.3 CLEANING (IN-SERVICE SHIPS). Refer to paragraph 551-1.16.3.

551-3.6.4 AIR COMPRESSOR (COMPLEX) CLEANING. Refer to paragraph 551-1.17.1.

SECTION 4.

COMPONENTS FOR ALL SHIPS

551-4.1 AIR COMPRESSION

551-4.1.1 BASIC METHODS. There are only two basic methods to compress air. One is the positive displacement method, the other is called the dynamic method. Both methods do work on the air to raise the pressure and as a consequence, generate heat which requires cooling to remove the heat.

551-4.1.1.1 Positive Displacement Method. The positive displacement method of compressing air employs pistons, vanes, screws, or lobes that move or rotate within a cylinder or housing and take successive scoops or volumes of air and force the air into a smaller volume. All positive displacement compressors have valves or ports that open and close in time to receive and retain the air once the elevated pressure has been reached. Positive displacement compressors are divided into two groups, reciprocating and rotary compressors, as follows:

a. Reciprocating compressors employ pistons or sometimes diaphragms that reciprocate in a cylinder fitted with suction and discharge valves.

b. Rotary compressors have rotating elements such as meshing straight or helical lobes, or eccentrically rotating vanes which take in and discharge gulps of air as the lobes or vanes pass the suction and discharge ports. Another type of rotary compressor is the Nash liquid ring compressor.

551-4.1.1.2 Dynamic Method. Dynamic compressors do not have valves or ports that open and close. Dynamic compressors take in a continuous flow of air and accelerate the air by means of impellers rotating at high speed. Once the air has attained a high velocity, it flows through diffusing elements in the compressor where it does work on itself, thereby increasing its pressure. This method of compressing air first converts mechanical energy to kinetic energy which then does the compression work. Dynamic compressors are suitable for very large capacity requirements, preferably much in excess of 1,000 cfm. High-pressure can be attained at simultaneous high capacity by means of multiple stages.

551-4.1.1.2.1 Dynamic compressors are further divided into centrifugal compressors in which the air flows radially from the impeller and is collected in a volute formed around the impeller, and axial flow compressors in which the air flows in an axial direction through successive stages of rotating impellers and stationary diffusers (stators). The axial flow compressor is used principally in gas turbine engines because it is a large capacity, low-pressure (LP) machine. The centrifugal compressor is suitable for developing somewhat higher pressures than the axial compressor.

551-4.1.2 COMMON COMPRESSOR TERMINOLOGY. The following definitions apply to various terms in common usage among compressor manufacturers and users (for additional definitions see Section 1).

a. Vertical compressors are those which have the cylinders in a vertical plane. Typical among compressors used in the Navy are vertical V and 3-cylinder radial, vertical W types, and L types.

b. Horizontal compressors are those which have the cylinders in a horizontal plane.

c. Angle compressors are those of the multicylinder type having the axis of the cylinders at an angle with each other.

d. Duplex compressors are those which have two parallel sets of compressing elements driven by individual cranks on a common shaft.

e. Single-acting compressors are those in which compression takes place on but one stroke per revolution in a cylinder.

f. Double-acting compressors are those in which compression takes place on both strokes per revolution in a compressing element.

g. Single-stage compressors are those in which compression from initial to final pressure is complete in a single compressing element.

h. Multistage compressors are those in which compression from initial to final pressure is completed in two or more stages.

i. Ratio of compression is the ratio of absolute discharge pressure to absolute intake pressure, absolute pressure being the sum of gauge pressure plus atmospheric pressure. This may refer to the ratio for any particular stage or to the compressor as a unit.

j. Reciprocating compressor displacement is the volume swept through by the first-stage piston or pistons expressed in cubic feet per minute. In double-acting compressors it is the volume swept through by both sides of the piston. Displacement of a multistage compressor is that of the first stage only.

k. Free air is air at the atmospheric pressure and temperature which exists at the place where the compressor is installed.

551-4.1.3 CAPACITY RATINGS. The capacity of a compressor is the amount of air actually compressed and delivered per minute or per hour. When expressed in cubic feet of free air, the capacity of a reciprocating compressor will be equal to the product of volumetric efficiency and the first-stage displacement. The volumetric efficiency is a percentage figure determined by tests and is usually stated by the manufacturer.

551-4.1.3.1 It has been customary to express the capacity of low and medium compressors (to 600 lb/in 2 g) in cubic feet of free air per minute. For high-pressure (HP) compressors, the capacity has been expressed in cubic feet of compressed air per hour; that is, at final discharge pressure. More recent practice is to express compressor capacity in pounds of dry air per minute or per hour, and to define the air inlet conditions (pressure, temperature, relative humidity) which prevail at the rated or specified capacity.

551-4.1.3.2 Regardless of how the capacity of a compressor is expressed, it should be understood that the weight of air per minute that a compressor takes in, compresses, and delivers will vary with the density and moisture content of the inlet air (that is, the pressure, temperature, and percent relative humidity). The capacity of a compressor (pounds dry air per minute) can vary by as much as 20 percent at sea level due to atmospheric changes. This is important to realize because the capacity variation will also be reflected in compressor brake horsepower.

551-4.1.4 NAVY SHIPBOARD AIR COMPRESSORS. Navy shipboard air compressors have acquired name designations that identify the type of compressor with the service for which it is used. This is a logical and useful method of classification because each service application has unique performance and design requirements so that it is possible to establish one specification or standard for each service, and thereby facilitate uniform procurement and ship application. Navy shipboard compressors fall into service categories as shown in Table 551-4-1.

Table 551-4-1 SERVICE CATEGORIES OF NAVY SHIPBOARD AIR COMPRESSORS

Service for Which Used	Type Recipro/ Rotary/ Centrifugal	Capacity Range Scfm	Discharge Pressure Range lb/in^2 g	H.P.	Ship Application
HP Air System	Recipro. [3]	60 to 100	3,000 to 5,000	30 to 75	General, Surface Ships and Submarines
HP O_2 N_2 Producer Plant	Recipro. [3]	100	3,000 to 5,000	60 to 75	Aircraft Carriers and Submarine Tenders
LP O_2 N_2 Producer Plant	Centrifugal [2]	1,750 or 1,900 max.	90 max.	400 to 450	Aircraft Carriers and Submarine Tenders
LP Air System	Centrifugal [2]	1,250 max.	100 to 125	350 to 400	Aircraft Carriers
LP Air System	Recipro. [3]	100 to 200	100 to 150	30 to 60	General, Surface Ships
LP Air System	Rotary [2] (Water-Flooded)	100	125	30	Patrol Frigates, CG-49, LHD-1, DDG-51
Pneumatic Controls (A.C.C.) [1] & C.A.	Rotary [2] Liquid-Piston	15 to 50	85 to 125	10 to 60	Submarines and Aircraft Carriers
PRAIRIE/MASKER	Centrifugal [2]	1,400	28 45	250 300	Destroyers, Frigates
Diesel Starting	Recipro.	10 50 20 200	600 450 to 600 600 300	7.5 25 15 50	Where required for diesel starting MCM, ASR-51
Ballast Blowing and Ventilation	Rotary [2] Helical Lobe	1,000 to 2,200	6 to 22	90 to 200	Submarines and Landing Ships Dock

NOTES:
1. P.D. - Positive displacement
   A.C.C. - Automatic combustion controls on fossil-fueled ships
   C.A. - Control air on nuclear ships
2. Indicates compressors deliver oil-free air
3. Indicates compressors deliver oil-free air when installed on new ships commencing in 1977

551-4.1.5 AIR COMPRESSOR LUBRICANTS. Current military specifications used for Navy compressor procurement require that the compressors be designed for use with the lubricant designated as Navy symbol 2190TEP, conforming to MIL-L-17331, except for the high-speed centrifugal compressors and cylinder lubrication for Ingersoll-Rand lubricated HP air compressors. Refer to equipment technical manuals and Navy advisories for lubricant recommendations on these compressors. It is advisable that this lubricant be used exclusively.

551-4.1.5.1 Dependence on trade name lubricants, which are sometimes called out by compressor manufacturers is not recommended because uniformity, quality, and availability of the lubricants cannot be assured. With consistent use of specified lubricants, operating personnel have the advantage of becoming accustomed to the lubricant's service characteristics such as appearance, consistency, and typical changes associated with use. Compressor performance, evaluation, and troubleshooting can proceed with greater confidence.

551-4.2 HIGH PRESSURE AIR COMPRESSORS

551-4.2.1 GENERAL. Navy standard HP air compressors are used to supply air to shipboard HP systems and to maintain the system pressure at the desired level, usually at nominal operating pressures of 3,000, 4,500 or

5,000 lb/in^2 g. HP air compressors are also installed to provide the air source for HP liquid Oxygen-Nitrogen (O_2 N_2) producer plants. Unlike commercial or industrial compressors, Navy HP compressors are of special design to make them suitable for combatant marine service and have become known as Navy standard HP air compressors because they have been standardized into several convenient sizes or classes.

551-4.2.2 UPDATING AIR COMPRESSORS. In the early 1970's, an installation program commenced to replace the conventional oil-lubricated Navy compressors and to provide new ships and submarines with oil-free compressors. Oil-free compressors are fitted with piston rings and piston guides which require no oil lubrication, and the compression stages are completely separated from the oil containing crankcase. These features ensure that air is compressed without using lubricating oil in the compression stages so that uncontaminated oil-free compressed air is delivered to the user. It should be kept in mind, however, that the absolute cleanliness of compressed air is dependent on the internal cleanliness of the air compressor and on the cleanliness of the intake air.

551-4.2.3 CLASSIFICATION. The classification of Navy HP air compressors was initially established in the military specification used for the purchase of these compressors. The class designation is often used in the manufacturer's technical manuals and denotes the nominal capacity, discharge pressure capability, and intended service. Table 551-4-2 shows the classification of both the oil-lubricated compressors and the new oil-free compressors. A number of small commercial or industrial HP compressors have also been installed under various interim programs or for special limited service. These have not been classified as Navy standard compressors and are usually referred to by the manufacturer's model number or by their capacity; for example, 4 cfh, 3,000 lb/in^2 g.

Table 551-4-2 NAVY HP AIR COMPRESSOR CLASSIFICATION

Oil Lubricated	**Nominal Capacity**	**Discharge Pressure**	**Service**
Special (MIL-C-23961)	18/30 cfh [1] (100 scfm)	5,000/3,000 lb/in^2	Submarine Tenders and Aircraft Carriers O_2 N_2 Producer Plants
Class A (MIL-C-18419)	20 cfh [1] (66 scfm)	3,000 lb/in^2	Surface Ships
Class AA (MIL-C-18419)	13 cfh [1] (66 scfm)	4,500 lb/in^2	Submarines
Class B (MIL-C-18419)	7 cfh [1] (24 scfm)	3,000 lb/in^2	Surface Ships
Class BB (MIL-C-18419)	4.5 cfh [1] (24 scfm)	4,500 lb/in^2	Surface Ships
Oil-Free (2)	Nominal Capacity	Discharge Pressure	Service
13 or 20 cfh [1]	265 lbs/hr	3,000 lb/in^2 (20 cfh) 4,500 lb/in^2 (13 cfh)	Surface Ships
30 cfh	100 scfm	3,000 lb/in^2 (30 cfm) 5,000 lb/in^2 (18 cfm)	Submarine Tenders and Aircraft Carriers
13 cfh	265 lbs/hr	4,500 lb/in^2	Submarines [3]

NOTES:
1. Cubic feet/hour measured at discharge conditions.
2. Compressors with dual ratings may operate at either condition with changes in pressure switches and relief valves.
3. Although submarine compressors have same ratings as used on surface ships, machinery arrangements are different due to different requirements for cooling and controls.

551-4.2.4 SHIPBOARD APPLICATION SYSTEMS. HP air compressors serve the HP compressed air systems installed on large ships and submarines. They also provide compressed air to HP liquid oxygen/nitrogen producer plants on submarine tenders and aircraft carriers. When serving compressed air systems on surface ships, the HP compressor maintains the system at a nominal operating system pressure of 3,000 or 4,500 lb/in^2 depending on the system design. Compressors are designed for the specific nominal operating pressure of the system served. Post-World War II submarines are equipped with 4,500 lb/in^2 HP air systems and flasks. This requires air compressors that can operate at a discharge pressure in excess of 4,500 lb/in^2 . The higher compressor discharge pressure is necessary to overcome pressure losses in the piping and compressed air-drying equipment so that the net delivery pressure to the air flasks will not be less than 4,500 lb/in^2 .

551-4.2.5 O_2 N_2 SERVICE. For O_2 N_2 producer service, special HP compressors have been provided. These compressors incorporate a capacity adjustment feature whereby the compressor delivery capacity can be closely matched to the air requirements of the $_2$ N_2 producer. Operating pressure varies over the range of 1,800 to 3,000 lb/in^2 . The HP O_2 N_2 producers are installed on submarine tenders and older aircraft carriers. Some of these ships have HP compressed air systems designed for 4,500 lb/in^2 g nominal operating pressure. On these ships the O_2 N_2 producing air compressors are also suitable for alternate service on the 4,500 lb/in^2 g compressed air system.

551-4.2.6 GENERAL DESCRIPTION. Navy standard HP compressors are multistage, reciprocating compressors having four, five, or six stages of compression. A multistage compressor is really a composite of several compressors (each stage being considered as one compressor) that are driven by a single common crankshaft. The air is compressed and cooled in each stage successively and discharged from the last stage to the ship's compressed air system. Figure 551-4-1 shows schematically such a composite four-stage compressor. Each stage consists of similar components such as an inlet valve, a piston and cylinder, a discharge valve, an air cooler, and a water separator. Each stage is identically instrumented, with discharge pressure gauges, an overpressure relief valve, and inlet and discharge temperature sensors for temperature indication and high temperature shutdown.

551-4.2.6.1 Each stage functions in the same manner. Air enters the cylinder through the inlet valve during the suction stroke of the piston and is compressed and discharged by way of the discharge valve during the compression stroke. The air is cooled in the cooler where excess moisture condenses to form water droplets; the mixture of air and water then enters a separator where the water is removed. Air is then ready to enter the next stage to repeat the cycle. Hence, the composite compressor does successive work on a fixed amount of air as the air moves from stage to stage. The number of compression stages required in an HP reciprocating compressor is established at the time the compressor is designed. Factors important in determining the number of stages are:

a. The required final discharge pressure

b. The ability to cool the air as pressure is raised

c. The capability to cool the air in each stage after compression

d. The permissible maximum temperature of the air and compressor components as the air is compressed in each stage.

551-4.2.6.2 The performance of each compression stage depends on the proper performance of the previous stage and can also be affected by malfunctioning of the succeeding stage because the discharge pressure and temperature of one stage controls the inlet pressure and temperature of the next stage. An understanding of these interstage relationships is necessary to successfully troubleshoot a malfunctioning compressor. In this regard it should also be noted that abnormal air leakage from one stage to a lower pressure stage at common boundary interfaces will upset the equilibrium of work and therefore be the cause of malfunctioning. The compression stages, shown schematically in Figure 551-4-1, are combined in a compact arrangement so that several pistons can be conveniently driven by one crankshaft and driver. Compactness is an important element in shipboard service where space is at a premium.

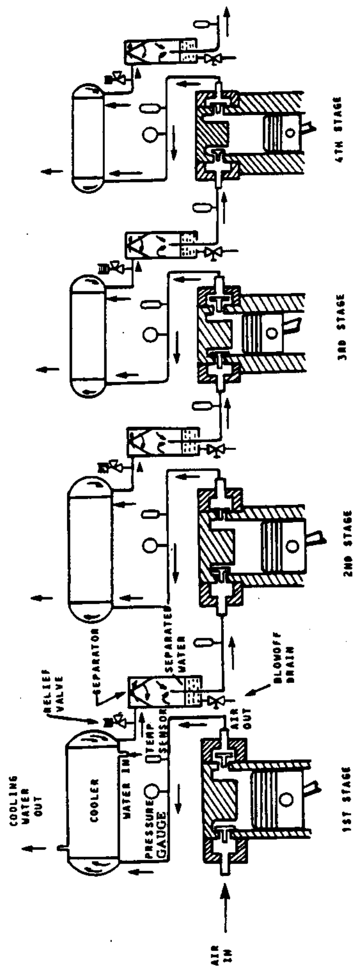


Figure 551-4-1 Four-Stage HP Air Compressor

551-4.2.7 CONFIGURATIONS. Various arrangements of combined compression stages are used, depending upon the manufacturer's preferences. Figure 551-4-2 and Figure 551-4-3 show multistage arrangements in which the cylinders are located side by side vertically above the crankcase. This is sometimes referred to as an in-line arrangement because the cylinders are lined up vertically in a plane common with the rotational axis of the crankshaft. The coolers, separators, and interconnecting piping are located to achieve compactness and maintenance access. The actual compression stage cylinders may be in the form of cylinder bores machined directly into the cylinder block, or the cylinders may be removable and replaceable sleeves or liners that are inserted into the cylinder block.

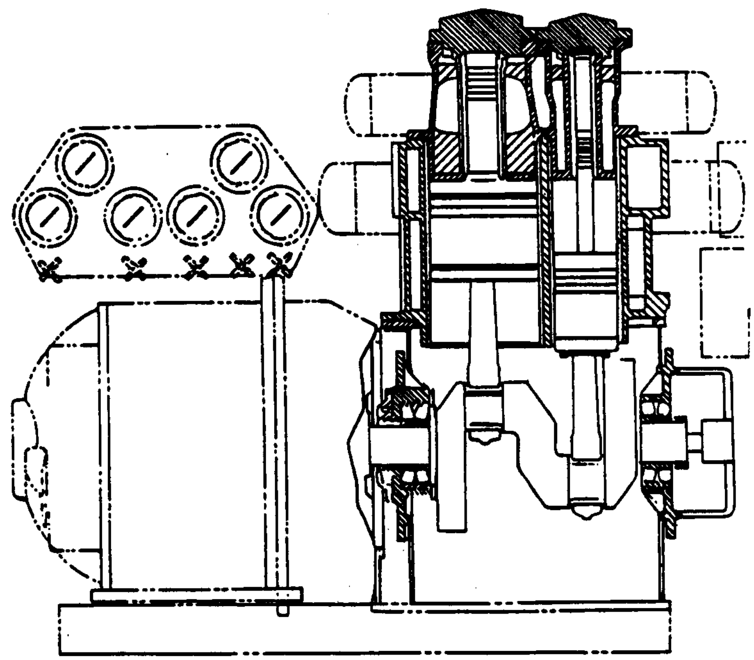


Figure 551-4-2 Oil-Lubricated HP Air Compressor Cylinder Arrangement

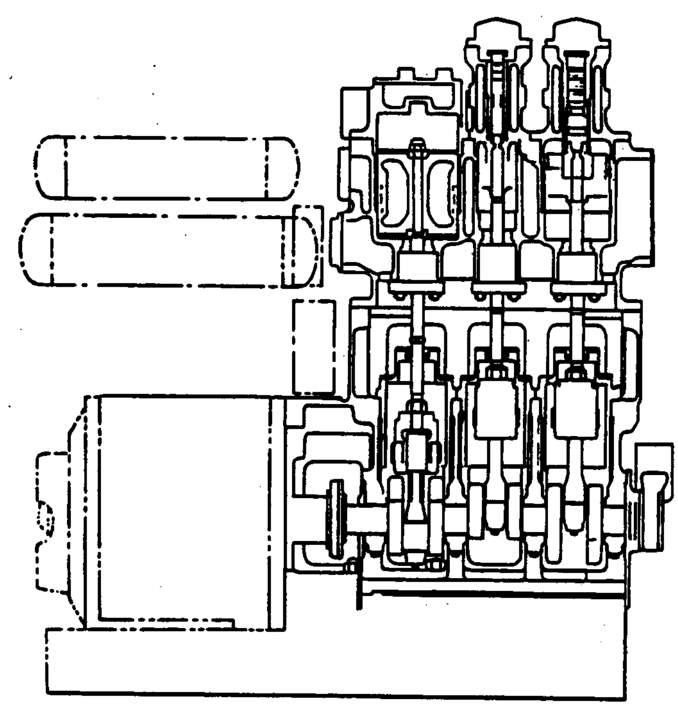


Figure 551-4-3 Oil-Free HP Air Compressor Cylinder Arrangement

551-4.2.8 PISTON AND CYLINDER COMPRESSION CYCLE. The inlet and discharge valves of a typical single-stage, single-acting compressor cylinder are located in the clearance space and communicate through ports in the cylinder head to the inlet and discharge connections. Operation is described in the following paragraphs.

551-4.2.8.1 Suction Stroke. When the compressor piston starts on its downward stroke, the air under pressure in the clearance space rapidly expands until the pressure falls below that on the opposite side of the inlet valve. This differential in pressure causes the inlet valve to open, admitting air to the cylinder. Air continues to be drawn into the cylinder until the piston reaches the bottom of its stroke.

551-4.2.8.2 Compression Stroke. As the piston starts upward, the air begins to compress until it has reached the same pressure as exists in the compressor intake, whereupon the inlet valve closes. As the piston continues upward, air is compressed until the pressure in the cylinder becomes great enough to open the discharge valve against the pressure of the valve springs and the pressure in the discharge line. From this point to the end of the stroke, the air compressed within the cylinder is discharged at practically constant pressure.

551-4.2.8.3 Volumetric Efficiency. The ratio of the distance between points 2 and 4, and the total length of the indicator card is known as the indicated volumetric efficiency, which is somewhat greater than the true volumetric efficiency as measured by more accurate means.

551-4.2.9 MAJOR COMPONENT PARTS. Major component parts of HP air compressors are described in the following paragraphs.

551-4.2.9.1 Pistons. Compressor pistons may be of a design to serve one compression stage or they may consist of two elements, each with its own set of piston rings, to serve two adjacent compression stages. Such a two-step piston is usually referred to as a stacked piston. Pistons also may be single-acting or double-acting. Single-acting pistons take suction and compress air on only one side. The single-acting piston carries one set of piston rings oriented for compression in only one direction and the associated cylinder incorporates only one set of suction and discharge valves. Double-acting pistons compress air and take suction on both sides; that is, as one side is performing the suction stroke, the other side is performing the compression stroke. A double-acting piston shall have a double-acting set of piston rings, which can seal for compression in either direction, and a double set of suction and discharge valves, one set at either end of the cylinder. A stacked piston shall not be confused with a double-acting piston. A stacked piston serves two cylinders of different diameters and therefore does the work for two separate stages of compression. A double-acting piston operates in one cylinder and does the work of only one stage (see Figure 551-4-4). A double-acting piston that operates in two cylinders does the work of two stages.

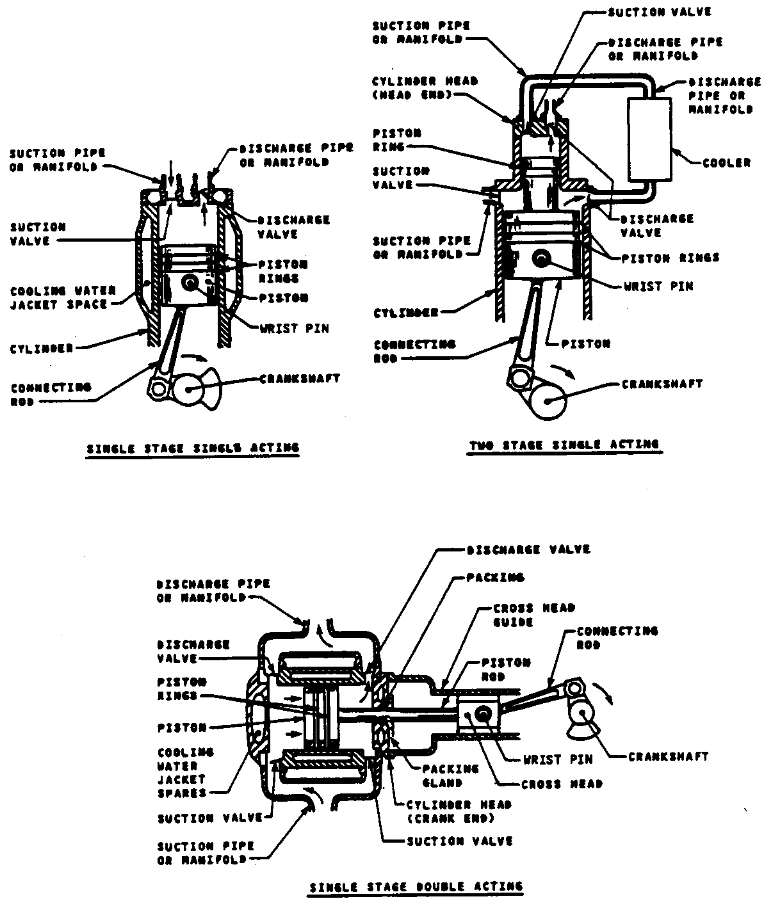


Figure 551-4-4 Variations in Piston and Cylinder Design

551-4.2.9.2 Suction and Discharge Valves. Air valves are the vital part of a compressor. All inlet and discharge valves of present day compressors are of the automatic type; that is, the opening and closing of the valves are caused solely by the difference in pressure between the air within the compressor cylinder and the external air on the opposite sides of the valves.

551-4.2.9.2.1 Thin plate, low lift valves are the preferred type and are now used in all compressors except for HP cylinders. Thin plate valves consist of a valve seat, valve plate, valve spring, and valve guard. In some models, the valve plate and valve spring are combined in a single flat spring strip. These valves are made in a variety of forms such as annular discs, thin section channels, strips, and more complicated flat plates, and are known by several names such as plate, feather, channel, and wafer. Thin plate, low lift valves have the following advantages over other valves:

a. Large areas for the passage of air which permit a low velocity of air through the valve thus improving the compression efficiency.

b. They open with minimum resistance and close promptly, thereby keeping the range of pressure inside the cylinder within limits close to that for which the compressor is designed.

c. Because of their light weight and low lift, they operate with a minimum of noise.

551-4.2.9.2.2 Modified poppet valves of the automatic type are employed in HP cylinders. They consist of a valve seat, valve, valve spring, and valve guide or cage. Common forms of valves are the mushroom and cup types.

551-4.2.9.2.3 For oil-free compressors, the valves are usually fitted with self-lubricating Teflon bushings or inserts to minimize wear in critical rubbing areas.

551-4.2.9.3 Running Gear. The power to move the pistons back and forth is transmitted from the driver to the pistons by means of mechanical linkages usually referred to as running gear. The running gear consists of the crankshaft with the main bearings, the connecting rods with rod bearings at the crankshaft, and wrist pin bearings at the pistons. The running gear components are contained in the crankcase.

551-4.2.9.3.1 On oil-free shipboard reciprocating compressors, where it is of prime importance that crankcase lubricating oil not be allowed to enter the compression stages, the compressor running gear includes crossheads located within the crankcase. In a running gear with crossheads, the connecting rods do not connect directly to the pistons but instead are connected with wrist pin bearings to a sliding shoe called a crosshead, that moves back and forth on guides or rails within the crankcase. The pistons are rigidly connected to the crossheads by means of piston rods. The crossheads absorb the side thrust of the connecting rods and impart true linear motion to the piston rods and piston. Piston rod oil seals are installed at the point where the piston rods exit from the crankcase, thereby confining the oil to the crankcase.

551-4.2.9.3.2 Crankshafts are generally a single forging. Duplex compressors have two crank throws, customarily 180 degrees apart for better balancing. Some compressors have counterweighted crank webs in which the counterweights are either an integral part of the forging, or are secured thereto by fitted bolts suitably locked to prevent loosening.

551-4.2.9.3.3 Main bearings for the crankshaft of modern naval compressors are generally sleeve-type bearings. In addition to the main bearings, each crankshaft shall include a thrust bearing to overcome any thrust that may be developed by the driving unit or reduction gear. This is to ensure satisfactory operation under conditions of listing, rolling, or pitching of the vessel in a seaway and in some installations to resist mechanical shock. Thrust bearings are generally of the ball-bearing type. On some compressors the thrust is taken between babbitted sides of main bearings and adjacent crank webs. In compressors provided with taper roller main bearings, additional thrust bearings are unnecessary.

551-4.2.9.3.4 Wrist pins are generally of the hollow type, hardened, and ground. The pins are fixed in bosses in the piston and are fitted with a bronze bushing in way of the connecting rod eye, or the pins are locked to the connecting rod and the bushings are pressed in the piston bosses. In two makes of compressors, a ball-and-socket joint is substituted for the conventional wrist pin construction. In this design the upper end of the connecting rod consists of a spherical ball. The spherical bronze socket is split in half normal to the connecting rod and secured to the piston by tap bolts.

551-4.2.9.3.5 Connecting rods of most modern naval compressors have bushed wrist pin ends. One design, however, has a split, wrist pin end, the connecting rod being secured to the pin by means of a suitably locked cap screw. The bushings are pressed in the piston bosses. In compressors of the trunk-piston type, the upper end of the connecting rod is fitted directly to the wrist pin on the piston. Where an additional stage is mounted above the trunk-piston, the piston rod is fitted into the crown of the trunk-piston. Crosshead construction is used on oil-free HP compressors.

551-4.2.9.3.6 Some newer design compressor pistons are driven through a swashplate rather than a crankshaft. The swashplate is a round plate mounted on an extension of the motor shaft which is angled at 15 degrees from the vertical. An anti-rotation device and bearings between the shaft and swashplate allow the swashplate to tip but not turn as the motor rotates. This tipping action causes the connecting rods attached to the periphery of the swashplate to move up and down causing each piston to compress air in each cylinder in turn.

551-4.2.9.4 Compressor Drive. Since World War II, Navy shipboard HP compressors have been driven by electric motors. Electric motor-driven HP air compressors are directly driven through a flexible coupling when the motor and compressor are designed for equal rpm. To conserve space, some direct-drive motor designs use a motor with only one bearing. The driven-end main bearing of the compressor serves as the second motor bearing. More conventional motor drives employ motor and compressor sheeves coupled by flexible belts. This is usually used when the motor rpm is higher than the compressor rpm. The compressor sheeve is designed to function as a flywheel. Some motor-driven compressors employ a pinion and bullgear drive. The bullgear is mounted on the crankshaft and acts as a flywheel and the pinion is driven directly by the motor.

551-4.2.10 COOLING SYSTEM. The work of compression generates heat. This heat is removed by a cooling system to prevent the compressed air and various compressor parts from reaching excessively high temperatures. In an HP reciprocating compressor, the compression cylinders are cooled by means of fresh water or treated distilled water which is circulated through cooling water passages in the cylinder block. When removable cylinder liners or cylinder sleeves are used, the cylinder block may incorporate wells or bores for the liners so that the cooling water does not come into direct contact with the cylinder liners (dry liners), or, alternately, the liner may be held in shoulders with 0-ring seals within the cylinder block so that the cylinder liners are wetted by the cooling water (wet liners). Cylinder jackets are fitted with handholes and covers so that the water spaces may be inspected and cleaned.

551-4.2.10.1 Joint Leakage. On many compressors, water passes directly through the joint between the cylinder and head. On such designs, extreme care shall be taken to see that the joint is properly gasketed to prevent leakage, which, if allowed to continue, would cause corrosion problems or more severe damage.

551-4.2.10.2 Air Cooling. In addition to cylinder cooling, each stage of an HP compressor has an air cooler in which the discharge air is cooled before it enters the next stage. The coolers are usually of shell and tube design. Compressed air is led through the tubes of the cooler, with the cooling water flowing through the shell and over the tubes. On some compressors this may be reversed on the low-pressure stages (first and second); that is, the cooling water flows through the tubes and the air through the shell. The coolers between stages are called intercoolers. The last cooler is the aftercooler. Various methods of cooling are described in the following paragraphs.

551-4.2.10.3 Oil-Free Compressor Cooling. Most oil-free compressors on surface ships employ a seawater cooling system for the intercoolers and aftercooler, and a secondary freshwater system for cylinder cooling. Corrosion protection for the cylinder cooling system is achieved by adding ethylene glycol anti-freeze with corrosion resisting additives to the cylinder cooling system. The compressor technical manual provides instructions for use of corrosion inhibitors. This is shown in Figure 551-4-5. A constant rate of flow and thermostatic temperature control are provided in the cylinder cooling system to ensure uniform operating conditions for the compression stages and to avoid detrimental excessive cooling of cylinders (causes condensation on cylinder walls which results in early catastrophic seal failure). On submarines and some surface ships, fresh water is used for cylinder cooling and for intercooler and aftercooler service. The principal reason for using only fresh water on submarines is to avoid exposing the compressor cooling water passages to seawater pressure.

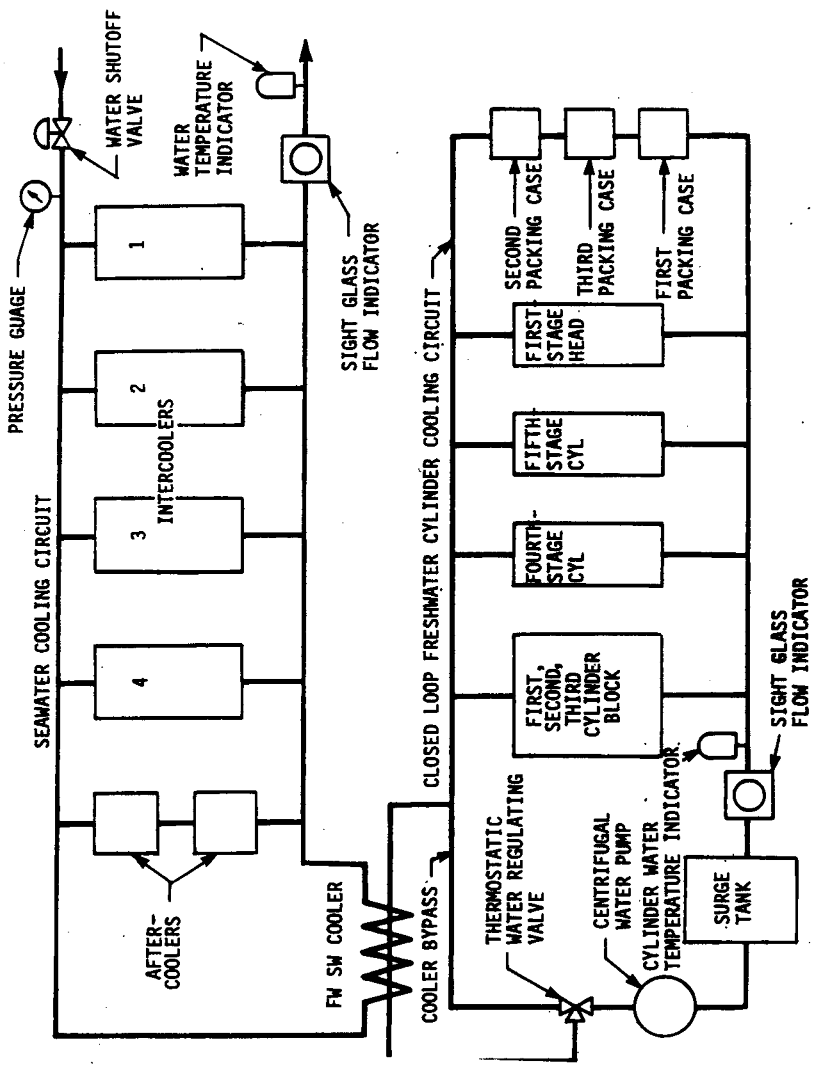


Figure 551-4-5 Cooling Water Flow Diagram

Figure 551-4-5 Cooling Water Flow Diagram

551-4.2.10.4 Oil Lubricated Compressor Cooling. On earlier air compressors, cooling is provided by a seawater system that serves the compression cylinders as well as the intercoolers and aftercooler. In these systems the seawater flows essentially in a series arrangement, first through the intercoolers and aftercooler and then to the compression cylinders. This ensures that the air entering the cylinders is always cooler than the valve chambers and cylinders, so that moisture condensation is minimized. However, with seawater temperatures substantially lower than 85° F, condensation may occur within the cylinders and discharge valve chambers (or cylinder heads) on the compression stroke. Also, due to the compactness of some compressor designs, low seawater temperatures cause the compressor frame and oil sump to reach sufficiently low temperatures so that condensation may occur within the oil sump with rapid water buildup and subsequent bearing failure.

551-4.2.10.4.1 To protect against overcooling on totally seawater-cooled compressors, it is recommended that cooling water be throttled so that seawater flow and the cooling effect in the compression cylinders is reduced. Excessive reduction in cooling water flow can result in hot spots in the cylinder areas where flow under normal conditions is perhaps marginal. In this regard it is necessary to follow the manufacturer's recommendations in the technical manual on any specific compressor.

551-4.2.10.5 Cooling Considerations. In all compressors fitted with thermostatically controlled freshwater cooling systems, the possibility of overcooling the cylinders occurs only when the thermostat is malfunctioning. The air cannot be cooled too much in the intercoolers and aftercooler. There are no detrimental effects from low air discharge temperatures from the coolers. The more the air is cooled in the intercoolers, the lower the brake horsepower, the more water is condensed within the cooler, the lower the chances of water condensing during the subsequent compression stroke.

551-4.2.10.6 Relief Valves. The water side of intercoolers and aftercoolers, with the exception of first- and second-stage intercoolers, are protected by relief valves or rupture disks. The air side is protected by the relief valves at the discharge of each compression stage.

551-4.2.11 WATER SEPARATION. As air is raised in pressure and cooled in each stage, the air looses its ability to retain the moisture that it normally retains at atmospheric pressure. This loss in moisture retention capability results in the rejection (by condensation) of the excess moisture in the intercoolers and aftercooler. The condensed moisture coalesces into water droplets and shall be separated from the compressed air after each compression stage so that it will not enter the succeeding stages, or be in the final discharge air. The water separators perform this function.

551-4.2.11.1 The mixture of water and compressed air from the intercoolers or aftercooler enters the separator tangentially at the top. By centrifugal action, change in direction, or impingement on baffles, the water is separated and collected in the lower half of the separator or other collecting sump. The compressed air, now free of water, flows to the next compression stage. The water collected in the separator or sump shall be regularly removed by manual draining or by automatic blowdown. Failure to do so or malfunctioning of the automatic blowdown system results in flooding of the separator and carryover of water to the succeeding stage.

551-4.2.11.2 Water carryover is detrimental to cylinder lubrication in oil lubricated compressors and rapidly destroys the Teflon compression seals and piston rings in oil-free compressors. On oil lubricated compressors, particularly of the design without crossheads, water carryover also results in water contamination of the crankcase oil supply.

551-4.2.11.3 The amount of water that is separated per hour in each separator depends on the moisture content of the inlet air, the efficiency or effectiveness of the separators, the discharge pressure at which the compressor is operating, and the cooling water supply temperature (the amount of cooling that is done in the cooler upstream of the separator). Under certain conditions there may be no water separated in the first-stage or even the second-stage separator. For water to become available for separation, the compression ratio for that stage shall exceed the ratio of the vapor pressures before and after compression.

551-4.2.12 AUTOMATIC SEPARATOR BLOWDOWN SYSTEM. Most HP compressors are fitted with a blowdown system that automatically drains the condensate from the water separators. The last compression stage separator may be drained automatically, or it may only be drained through the unloader valve on shutdown. The automatic separator drain system may operate on a regular timed cycle or may be triggered by condensate level switches. Hand valves for manual condensate draining are also provided for use when the automatic system is inoperative.

551-4.2.12.1 There are two basic types of automatic condensate drain system. One consists of individual stage separator solenoid valves, which are opened and closed to drain condensate from the separators. The solenoid valves may be activated on a timed cycle or by condensate level switches located inside the separators. The drain valves for the higher pressure stages may use pilot air operated valves, where the pilot air is controlled by a solenoid valve. The lower pressure stages use direct acting solenoid valves.

551-4.2.12.2 The second type of automatic condensate drain system consists of a motor driven rotary drain valve and an accumulator tank. The slowly rotating drain valve contains a rotor with drilled passageways. This rotor lines up individual stage separator ports to the accumulator tank as it turns. This allows each stage to drain its condensate to the accumulator tank on a timed cycle. The rotor then lines up its passageways so that the accumulator tank drains to the bilge. A series of check valves in the tubing system to the separators prevents blowback from high pressure to low pressure stages. The accumulator is blown down twice per cycle to allow for possible freeze-up clogging of the drain line to the bilge due to the high pressures found in the accumulator tank.

551-4.2.13 CYLINDER LUBRICATION. The cylindrical area traversed by the piston rings within the cylinder of a reciprocating air compressor requires lubrication to minimize wear of the cylinder surface and the piston rings. Lubrication of the ring travel area also facilitates sealing for more efficient compression and minimizes frictional heat. Cylinder lubrication is provided on oil lubricated compressors by small oil pumping units called lubricators which inject a definite quantity of lubricating oil into each compression stage at regular intervals. The lubricators are usually driven directly or indirectly by a chain or gear train from the compressor crankshaft.

551-4.2.13.1 The compressor manufacturer’s recommended rate or quantity of oil per minute that is required to be pumped to each compression cylinder shall be carefully determined and checked to ensure that lubrication is provided as specified. Too little oil may cause high temperatures and rapid wear. Too much oil will cause oil carbonization on the valves, encrustation within intercoolers, and may cause oil carryover into the compressed air system. Because oil carryover into the compressed air system is undesirable, oil-free compressors have been developed in which no lubricant is used in the piston/cylinder area. These are now used on all new ships.

551-4.2.13.2 On oil-free compressors, cylinder lubrication is provided by the self-lubricating quality of the Teflon of which the piston rings and seals are made. The lubricating quality of Teflon when used as piston rings is greatly diminished in the presence of water. Adequate water separation in the interstage water separators is therefore extremely important.

551-4.2.14 RUNNING GEAR LUBRICATION. HP compressors employ a conventional forced feed lubrication system of which the principal elements are the oil reservoir, oil pump, temperature indicator, oil failure pressure switch, oil filter, and the drilled oil passages in the crankshaft and connecting rods. Design details and components vary among the compressors. The type of oil filter provided will dictate the servicing required. Oil coolers are usually not provided. Where installed, excessive cooling of the lubricating oil should be avoided to prevent moisture condensation.

551-4.2.14.1 In HP compressors of the type in which the compression cylinders are open to the crankcase, the contamination of the crankcase lube oil with water and wear debris is an almost continuous process. Therefore, it is not sufficient to regularly monitor the crankcase oil level; it also requires inspection for the presence of water on a regular basis. Since free water will sink to the bottom of the oil sump under quiescent conditions, sampling at the lube oil sump drain is necessary. As indicated in the technical manual for the specific compressor, the changing of the crankcase oil at frequent regular intervals is mandatory, particularly for compressors in which the compression stages are not fully closed off from the crankcase.

551-4.2.14.2 Oil-free compressors with which all new ships are being fitted employ a crankcase fully separated from the compression stages. This promotes both long oil life and minimized crankcase breather emissions. The crankcase breather shall never be connected to the compressor suction on oil-free compressors. In the event lube oil cooling is required on oil-free compressors, the cylinder cooling water system serves the oil cooler. This prevents overcooling of the lube oil.

551-4.2.15 CRANKCASE BREATHER. The air breather on the crankcase oil reservoir minimizes pressure fluctuations and prevents pressure buildup in the crankcase. The effluent from the breather contains oil essentially in the liquid phase in the form of fine mist. The breather incorporates a coalescing element such as steel wool, whereby the oil mist is caused to coalesce and run back into the oil sump. Some of the mist will escape as the air moves in and out through the breather. Maintaining the coalescing element in clean condition will minimize the dispersal of oil mist to the machinery space.

551-4.2.15.1 On some of the later oil lubricated compressors, the crankcase breather terminates in the immediate vicinity of the compressor suction inlet, so that the emitted oil mist is fully drawn into the suction of the air compressor, thereby preventing contamination of the machinery space. The ingestion by the compressor of the crankcase breather effluent helps lubricate the piston rings and cylinder of the first stage but is only permissible on oil-lubricated compressors; that is, compressors with forced feed cylinder lubricators. Of great importance is an appreciation of the fact that too much oil can enter the compressor suction due to one or more of the following causes:

a. Excessive piston blowby due to worn piston rings and cylinders

b. Oil foaming due to water contamination or mixing of incompatible lubricants

c. Excessively high oil level due to water accumulation in the crankcase or improper oil filling.

551-4.2.16 CAPACITY ADJUSTMENT. The nominal 20 to 30 cfh HP air compressors installed on aircraft carriers and submarine tenders and used for O_2 N_2 producer service, incorporate a capacity adjustment feature, whereby the compressor capacity can be adjusted to match the air requirement of the O_2 N_2 producer plant served by the compressor. The feature consists of a threaded screw with locking device attached to a movable plate, whereby the first-stage clearance pocket can be reduced or enlarged. On some compressors the movable plate is the discharge valve itself. A change in the volume of the clearance pocket changes the volumetric efficiency and therefore the free air capacity of the compressor. An increase in clearance results in a decrease in capacity.

551-4.2.17 TEMPERATURE MONITOR. Electric or electronic temperature monitors are installed in place of common thermometers. The temperature sensors are of the resistance type and suitably housed for insertion into airstream or fluid to be measured. The monitor provides temperature readout for all critical temperatures such as lube oil, cooling water, and air inlet and outlet temperature for each stage. The monitor provides continuous monitoring of individual stage air discharge temperatures and automatic shutdown when the high-temperature setpoint is reached. Test, calibration, and adjustment features are provided. As a minimum, a Power On lamp and an Emergency Shutdown indicating lamp are provided.

551-4.2.18 EMERGENCY SHUTDOWN DEVICES. Automatic emergency shutdown of the compressor is usually provided for the following:

a. Failure to develop oil pressure on startup

b. Loss of oil pressure during operation

c. High air discharge temperature from any stage

d. Failure of the cylinder cooling system (oil-free compressor only)

e. Failure of the condensate drain system (oil-free compressor only).

551-4.2.19 UNLOADING SYSTEM. The unloading systems on HP compressors are designed to remove all but the friction load from the compressor, to permit starting without excessively loading the driver. All air piping and compressor components in the air system and the condensate drain system are depressurized on shutdown of the compressor. This is accomplished by means of hydraulic, pneumatic, or solenoid actuated operators and valves which act to open the unloading valve on the last stage(s) of the compressor. Unloading is initiated by any of the manual and automatic shutdown switches.

551-4.2.20 OPERATING CONTROLS. The compressors are provided with an On-Off pushbutton station and a two-position Manual-Automatic selector switch at the motor controller. An automatic pressure switch with two sets of electrical contacts senses compressor discharge pressure and starts and stops the compressor when the selector switch is on Automatic. In the Manual position of the selector switch, the compressor will not restart automatically but stops when the high-pressure contacts open on the pressure switch. On submarines, the automatic mode is usually not provided.

551-4.2.21 BACK PRESSURE REGULATING VALVE. HP oil-free compressors have a back pressure regulating valve installed in the air discharge line just downstream of the aftercooler separator. This valve is set to maintain a back pressure of approximately 2,000 lb/in^2 on the last compression stage. The valve is closed on compressor startup, so that the discharge pressure is built up rapidly, and opens on reaching a 2,000 lb/in^2 minimum back pressure. The rapid build up of back pressure is necessary to assist the Teflon sleeve seal on the fifth-stage piston (and sixth stage where provided) to seat and seal properly. Proper seating of this seal depends on the differential pressure across the seal, particularly when the seal is relatively new.

551-4.2.22 SERVICE CONSIDERATIONS. HP compressors are complex machines that require careful attention to certain aspects of their design, as well as proper maintenance for their successful operation. The following paragraphs are intended to point out the maintenance and operating considerations that should be understood for satisfactory operation of the compressor.

551-4.2.22.1 Concerns Before Starting. Authority to operate the compressor should be obtained before the start of any checkout procedures. When possible, concurrence should be obtained from the person responsible for maintenance that the compressor is ready for use. These steps are intended to ensure that the engineering department is ready for the compressor to be used. It also ensures that after the prestart inspection and checkout has been conducted, the compressor is ready for operation. To establish the specific startup procedures, the operator is concerned in three principal areas: Previous Status, Operational Readiness, and System Acceptability. These areas influence the approach to starting a compressor as described in the following paragraphs.

551-4.2.22.1.1 Previous Status. Recent history and past use of the compressor will indicate the probable condition of the compressor and the amount of pre-startup inspection required. For example, a compressor that has been in daily use for some time has an established performance record and will require a less critical inspection than would a recently overhauled machine just being placed in service or a compressor that has not been recently used.

551-4.2.22.1.2 Operational Readiness. A thorough knowledge of the condition of the compressor and associated systems shall be available to the operator before startup. This is essential so that potential problems will be recognized and corrective action taken before placing the compressor in operation. Part of the necessary information will be obtained when previous status is determined and part will be obtained with the inspection immediately preceding compressor start-up. General considerations and cautionary notes applicable to this pre-startup inspection are noted below. The prestartup instructions contained in the compressor and system technical manuals should be used for specific guidance. Prestartup procedure is as follows:

1. To prevent accidental startup, the compressor controller circuit should be deenergized and tagged **Out of Service** during the pre-startup inspection.
2. Inspect the compressor assembly and its immediate vicinity, including the deck and overhead, to ensure foreign objects such as rags, tools, and so forth, will not interfere with the operation of the machine. When making this inspection, pay particular attention to areas of recent repairs.
3. The compressor assembly should be inspected for evidence of water or oil leaks and mechanical damage such as bent tubing or broken parts. This is especially necessary during shipyard periods or if major work has been accomplished in the vicinity of the compressor when the machine may have been used as a stepladder or workbench.
4. To operate satisfactorily, the compressor cooling system shall be full of liquid; that is, completely vented and expansion tank filled to operating level. Cooling system strainers, when installed, should be clean and all valves in the piping carrying the cooling water, except those designated as control valves, should be fully open. When possible, such as when piping is arranged to supply cooling water from the ship's system, the actual flow in the cooling system should be verified by observing pressure gauges or sight flow indicators.
5. On compressors with the crankcase open to the cylinders, confirm that the crankcase lubricating oil is not contaminated with water by taking a sample from the sump for visual inspection. On all compressors, ensure that oil level in crankcase and lubricator (if installed) is at proper level.
6. Jack over the compressor by hand at least two revolutions to ensure the rotating parts turn freely.
7. Close the switch in the electrical system supplying the compressor controller.
8. Perform the available tests to confirm that the temperature monitors, alarms, and automatic safety shutdown are operational.
9. Verify that all pressure gauge isolation valves are open.
10. Prelubricate the cylinders if required.
11. Alert any people in the vicinity of the compressor.

551-4.2.22.1.3 System Acceptability. The HP air system from the compressor to the receiver shall be lined up and in a suitable condition to receive the air discharged by the compressor. The prestart inspection shall, therefore, include an inspection of the valve lineup to the intended receiver and a verification that the air system filter, separators, and other accessories are in operating condition.

551-4.2.22.2 Concerns During Operation. From the operator standpoint, there are three periods during the operating cycle that shall be considered. The first is the Initial Start Period which begins when the start button is depressed. This period blends into the Warmup Period as temperatures and pressures are gradually stabilized. The third period is Normal Operation. This period starts after steady-state operation is attained and all the inspections and adjustments required during the warmup period are completed. Further details of these stages are provided in the following paragraphs.

551-4.2.22.2.1 Initial Start Period (1 to 2 minutes). From the time the compressor starts to turn over until it is up to speed and the operating pressures are reached in each stage, the operator shall be especially alert for unusual noises, vibrations, or pressure readings that might indicate a problem. Particular attention should be paid to the system air pressures to see that the stage pressures come up in sequence, indicating that each stage is functioning properly and that the unloader has allowed the compressor to load. During this period, the operator shall, insofar as possible, be in a position to see at a glance the condition of the compressor system. The problems identified at this point in the operation of the compressor, when accompanied by a fast shutdown, can save a great deal of downtime and effort that would be required not only to correct the problem but also to repair resulting damage.

551-4.2.22.2.2 Warmup Period (about 1 hour). During this period, pressures and temperatures should stabilize within normal ranges. The functioning of auxiliary equipment such as temperature monitors, lubricating oil pump, and lubricators, should be confirmed. The following specific checks should be made.

1. Verify proper cooling water flow by observing the flow indicator and the stage discharge air temperatures. On compressors having freshwater circulating pumps, verify that the circulating water pump is vented and that the discharge pressure gauge for the pump indicates satisfactory operation. This is especially important if the cooling system was drained and refilled during the last shutdown period.
2. Adjust the cooling water flow control valve or the thermostatically operated flow control valve as applicable, to obtain the water temperature rise through the compressor called for in the compressor technical manual.
3. Check adjustment of all pressure gauge isolation valves to ensure that they are open and adjusted to prevent excessive movement of the gauge pointer due to system pressure fluctuations.
4. Check under and around the compressor for signs of oil or water leaks.
5. Check air piping for leaks.
6. Carefully inspect the operation of the automatic separator drain system through at least one complete cycle of operation.
7. On oil-free compressors, observe the piston rods through the inspection point above the crankcase. There should be no indications of oil on the lower end of the rod or air and water leaks at the upper end of the rod.

551-4.2.22.2.3 Normal Operating Period. During normal operation, a systematic monitoring program should be established to ensure prompt identification of any unusual conditions. This program should include the following:

1. Regularly inspect the supply of expendable fluids such as cooling water and lubricants in the compressor system. Replenish as necessary. Test the monitoring and alarm systems. Check calibration of resistance-type thermometers if such test is provided. These inspections should be conducted at least once each hour unless experience indicates a more frequent inspection is required.
2. Regularly inspect the operation of the lubricators on cylinder lubricated compressors.
3. Verify the satisfactory operation of the automatic condensate drain system at least once each hour by operating the manual blowdown and observing the quantity of condensate released. Satisfactory operation is indicated if, based upon experience, a normal quantity of condensate is released.
4. Record all hourly readings carefully and compare them with previous readings. Changes from previous readings shall be explained or consideration should be given to shutting down the compressor until the cause is determined. Gauge readings provide a very important indication of the condition of the compressor.
5. Include in the operator’s normal surveillance procedures the applicable inspections recommended in the compressor technical manual.

6. Persons attempting to correct any leaks or other disarrangements when the associated compressor is operating always run the risk of injury from accidental contact with the rotating parts or pressurized components. Stop the compressor before attempting repairs.
7. The tightening of a leaking air fitting may well cause a complete blowout. Therefore, except under the most unusual circumstances, never attempt to stop an air leak when the leaking joint is under pressure.

551-4.2.22.3 Preventive Maintenance. Because of the need to support planned operations with reliable equipment, the Navy has selected a preventive maintenance program that will ensure, insofar as practical, continued satisfactory operation of equipment between scheduled shutdowns. This is the Planned Maintenance System (PMS) required for naval ships. A preventive maintenance program may initially be developed by the manufacturer of the compressor. Using the PMS, this program is then updated as operating experience indicates, to develop a system that will avoid any unscheduled shutdown insofar as possible.

551-4.2.22.4 Corrective Maintenance. Corrective maintenance is the process of correcting faults or unsatisfactory conditions observed when carrying out the routine inspections of preventive maintenance. Corrective maintenance is discussed in compressor technical manuals in the form of diagrams, sketches, photographs, or troubleshooting charts. That information is designed to provide a starting point for the operator performing corrective maintenance. When equipment is disassembled for corrective maintenance, its condition should be observed so that indications of wear, failure, carbon buildup, and so forth can be used to update the PMS program for the compressor. This inspection may also indicate the need for design change. Recommendations for design changes should be forwarded to the Naval Sea Systems Command (NAVSEA) for approval and implementation.

551-4.2.22.5 Deactivation and Preservation. When a compressor cannot be operated at least once a week, special precautions shall be taken to reduce deterioration. Untreated, this deterioration will accelerate with time and affect all parts of the compressor. Small amounts of rust will accumulate in the cylinders that will increase piston ring wear when the compressor is started. These rust particles will work through the system, generally increasing wear rates. Corrosion in cooling systems will accelerate and solids in the water will settle and tend to harden in piping, coolers, and cylinder jackets. Contaminants in the lubricating oil, such as metal particles and water, will settle in bearings causing rusting and increasing wear upon startup. Deterioration may be the result of corrosion caused by oxidation (rusting) or the combination of dissimilar materials such as under packing glands, seals, and motor brushes. Oils or other preservatives can be used to protect the metals that are subject to rusting except where prohibited on oil-free compressors.

551-4.2.22.5.1 The procedures that should be followed to obtain the necessary protection depend on the specific compressor design and the storage environment. In every case, adequate protection from the elements and industrial debris shall be the first consideration. Specific requirements for the deactivation and preservation of out-of-service compressors are contained in the manufacturer’s technical manuals. The guidelines in the following paragraphs should be observed to the extent practicable.

551-4.2.22.5.2 An operational out-of-service compressor can be maintained in an availability status by regularly operating the compressor once a week, for a minimum of 1 hour at close to rated discharge pressure. This is the preferred method of preservation and may be used indefinitely.

551-4.2.22.5.3 If weekly operation is not feasible due to disrepair or lack of service, the compressor may be retained operational or in an awaiting repair status for up to 90 days by jacking the compressor over weekly, a minimum of six revolutions in succession. The cooling water systems should be drained, flushed, and dried with warm low-pressure air. The cylinders of oil lubricated compressors (having cylinder lubricators) should be sprayed once every other week with 1 or 2 cm3 of Navy symbol 2190TEP oil through one of the valve ports (remove valve and replace). Do not spray oil into the cylinder or valve chambers of oil-free compressors.

551-4.2.22.5.4 For nonoperational compressors placed out-of-service for periods longer than 90 days, deactivation and preservation should be accomplished according to the approved procedures for the specific compressor as set forth in the manufacturer's technical manual.

551-4.3 LP SHIPS' SERVICE COMPRESSORS

551-4.3.1 GENERAL. The LP ships' service air compressors include a variety of oil-free compressors, delivering compressed air at discharge pressure from 80 to 150 lb/in^2 . In addition to the regular ships' service air compressors, many different compressors were originally installed in ships, providing specialized compressed air requirements for pneumatic combustion controls, oxygen generator controls, electronic dry air systems, and other special services.

551-4.3.2 LP SYSTEM UPGRADES. In current practice on new ships, these requirements are now provided from a standardized general LP ships' service air system which segregates the nonvital and the vital services by means of priority valves and which is served by new standard oil-free LP ships' service compressor. For the ships already in service, alteration programs have been under way since 1970 to improve and standardize the LP ships' service compressed air systems. With respect to air compressors, these programs replaced the various oil lubricated reciprocating compressors with standard oil-free compressors of the type already in service on new ships.

551-4.3.3 OIL-FREE COMPRESSORS. The oil-free ships' service compressors now installed on most ships are listed in Table 551-4-2. Only the oil-free compressors are described in subsequent paragraphs and consist of the following:

a. Reciprocating compressors

b. Rotary water-flooded helical screw compressors

c. Nash water ring compressors

d. Centrifugal compressors.

551-4.3.4 RECIPROCATING COMPRESSORS. Oil-free reciprocating compressors were designed in two capacities: 100 scfm and 200 scfm. They are water-cooled, two-stage compressors operating at a discharge pressure of 125 to 150 lb/in^2 g. The design is very similar to the oil-free HP compressors. One design is actually identical to the oil-free HP compressor made by the same manufacturer, except that the last three stages of the HP compressor are omitted. The descriptions contained in paragraphs 551-4.2.6 through 551-4.2.16, pertaining specifically to oil-free compressors, are also applicable to LP compressors. The configuration of typical oil-free LP compressors is shown in Figure 551-4-6 and Figure 551-4-7.

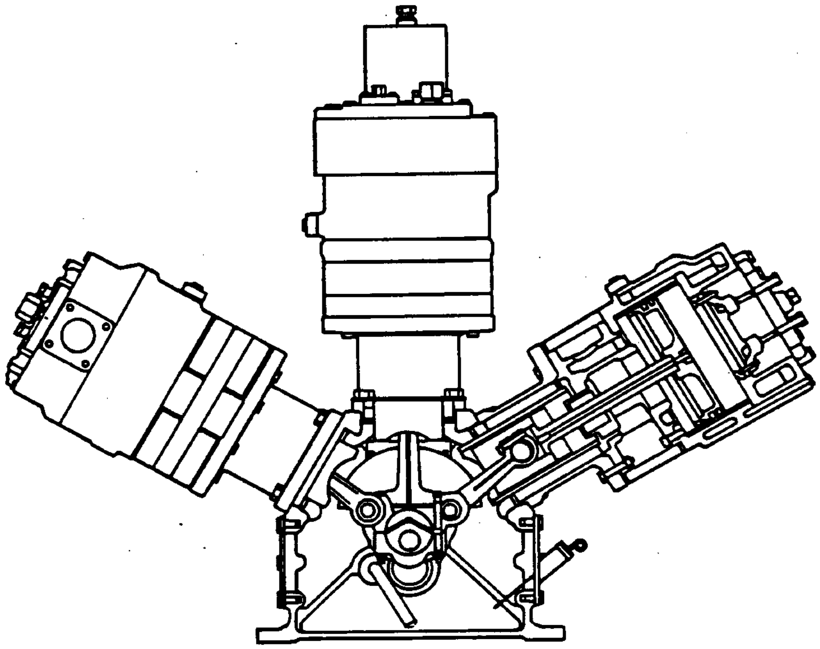


Figure 551-4-6 Oil-Free W-Type Compressor

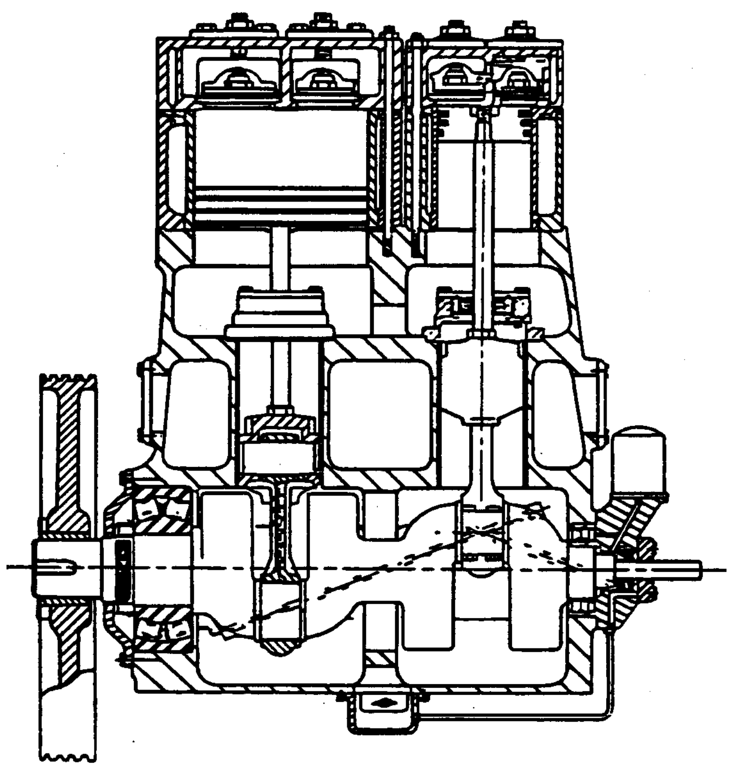


Figure 551-4-7 Oil-Free Two-Stage In-Line Compressor

551-4.3.4.1 Features. There are a number of features on HP compressors that are not normally furnished on oil-free LP compressors. Only two stages of compression are required for LP reciprocating compressors. Truncated or steepled pistons are not used. In place of an electronic temperature monitor, conventional dial-type temperature indicators are used, and high temperature shutdown is accomplished by temperature switches. The automatic drain system, the unloading system, and the control system are described in the following paragraphs.

551-4.3.4.2 Condensate Drain System. The first- and second-stage condensate separators are provided with condensate collecting compartments or separate condensate collecting tanks. Automatic draining of the collecting tanks is usually accomplished by means of a timing clock and solenoid-operated drain valves or float switches. Drainage takes place at 10-minute intervals. Bypass valves permit manual draining. Manual draining, when required, should be done at intervals not exceeding 30 minutes. Preferably, intervals should be shorter since the holding tanks are sized for a 30-minute collecting capacity under high humidity operating conditions.

551-4.3.4.3 Unloading. Different methods of unloading the compressors are used depending on the manufacturer's preference. One design employs suction valve lifters, whereby pneumatic diaphragm or piston actuated fingers hold open the suction valve plates for each stage on signal from the control system. An alternate design consists of solenoid-operated air blowoff valves in the discharge line of each stage. These valves discharge air to the atmosphere by way of a suitable silencer. The unloading feature permits operation of the compressor in a cyclic load/unload mode, in response to discharge pressure, and reduces start-stop cycling of the compressor. The unloaders also permit compressor starting at reduced load.

551-4.3.4.4 Operating Controls. When the ON pushbutton at the motor controller is pressed, the compressor is placed under the control of a pressure switch which senses air received or ship system pressure. On reaching the cutout pressure setting, the pressure switch actuates the unloaders and the timer. The compressor then continues to run in unloaded mode until the cut-in pressure setting is reached, whereupon the pressure switch deactivates the unloader and the compressor again delivers compressed air to the system. If the compressor has not reloaded after a time interval of approximately 10 minutes, the timer stops the compressor. The timer automatically resets when the compressor reloads or is shut down. The compressor automatically restarts by action of the pressure switch at the cut-in pressure setting as long as the OFF pushbutton is not depressed. Depressing the OFF pushbutton deactivates the electrical controls and removes the compressor from service.

551-4.3.4.4.1 Some multicompressor installations are provided with an additional control feature. This feature permits the operator to select any one of the individually set (cut-in and cutout) pressure switches to control any one of the installed compressors. Hence, the wear due to running time can be evenly distributed among each of the compressors by changing the lead function (first to cut in on a decreasing pressure signal) to any one of the installed compressors.

551-4.3.4.5 Emergency Shutdown. On most of the new oil-free compressors, the control system incorporates an automatic emergency shutdown feature which responds to abnormal critical failure symptoms detected by various surveillance devices such as high air temperature switches, lube oil, cooling water, and condensate drainage failure switches. High discharge temperatures are monitored at the air discharge of each stage. Lube oil, cooling water, and condensate drainage are monitored in a manner similar to that described for HP compressors. Automatic compressor shutdown on failure indication is intended to prevent compressor damage and major failure. It is therefore necessary to review the manufacturer's technical manual to become familiar with the causes of failure symptoms and the corrective actions.

551-4.3.4.6 Service Considerations. The service considerations discussed in paragraphs 551-4.2.22 through 551-4.2.22.2.3 for HP compressors are fully applicable to LP reciprocating compressors.

551-4.3.5 ROTARY WATER-FLOODED HELICAL SCREW COMPRESSORS. These new rotary compressors are the result of a Navy-sponsored development program to adapt oil-free rotary compressors for shipboard low-pressure service. The rotary compressor is an improvement over the reciprocating compressor because it weighs 40 percent less, occupies 40 percent less space, and has fewer parts. It is also potentially quieter in operation and more reliable then the reciprocating compressors because there is no reciprocating motion and no detrimental effects due to moisture in the air. However, the reliability of the compressor does depend on precision manufacture, scrupulous adherence to quality control during manufacture and assembly, meticulous attention to lubrication and compressor alignment, and strict adherence to the operating and maintenance requirements stipulated in the manufacturer's technical manuals and the PMS.

551-4.3.5.1 Two Parallel Meshing Screw. The rotary, water-flooded helical screw compressor, as the name indicates, is a rotary positive displacement compressor employing two parallel meshing helical screws rotating in a common housing. The endbells of the housing act as endplates with air inlet ports on one end and discharge ports on the other end. The endbells also contain shaft seals, bearings, and timing gears.

551-4.3.5.2 Air Compression. Inlet air is trapped in the space between the rotating helical screws, and the housing as the endfaces of the screws move past the inlet ports. The helical lobes rotate toward each other as they mesh and displace the trapped air volume which becomes smaller and smaller as it converges toward the compressor discharge endplate. When the air volume has been sufficiently reduced with the desired increase in air pressure, the endplate ports become exposed and the screws discharge the compressed air to the system.

551-4.3.5.3 Timing Gears. Timing gears prevent metal-to-metal contact between the meshing helical screw (rotors). Also, there is no metal-to-metal contact (water seals, lubricates, and cools) between the rotating and stationary parts within the rotor housing.

551-4.3.5.4 Water Sealing. To reduce the clearances and minimize air leakage (sometimes called slip), fresh water is injected into the inlet air at the compressor inlet at a controlled rate. This water is entrained in the air and passes through the compressor. During this passage, the water takes up the heat of compression. After being separated from the compressed air in a water separator and cooled, it is recirculated to the compressor inlet for reinjection. The fresh water recirculation and injection is maintained by the differential air pressure of the compressor suction pressure and discharge pressure. No water pump is employed. The rate of recirculation has been optimized and is controlled by the pressure drop characteristics designed into the recirculation system.

551-4.3.5.5 Compression Ratio. The air is compressed at a compression ratio of 9.5 in a single stage. Compression takes place virtually as in isothermal process. Even though power is expended to circulate the injection water, the overall compressor efficiency is comparable to the reciprocating compressor. The compressor is installed in only one size, having a capacity of 100 cfm of free air at a discharge pressure of 125 lb/in^2 g.

551-4.3.5.6 Drive. The compressor is directly driven through a flexible coupling by a 30-horsepower electric motor at a full-load speed of 3,535 rpm. The direct drive is coupled to the male rotor which has four helical lobes. The female rotor has six helical grooves with which the male lobes engage, although there is no meshing contact. The female rotor turns at two-thirds the rotative speed of the male rotor.

551-4.3.5.6.1 On the compressor end, opposite to the drive end, a set of helical timing gears is mounted on the rotor shafts. The gear on the male rotor drives the gear on the female rotor. It is the proper setting or adjustment of the timing gears which ensures that no metal-to-metal contact will occur between the male and female rotor lobes and grooves. The setting or timing of the timing gears takes into account the backlash of the gears themselves as well as the backlash of the rotors.

551-4.3.5.6.2 Each gear consists of a gear hub and a gear rim so that the gear rim can be rotated on the hub and then locked to the hub. This facilitates timing gear adjustment. Instructions for setting the timing gears are contained in the manufacturer’s technical manual and shall be followed exactly. Work on the timing gears should be accomplished by experienced personnel, and only when all the specified special tools and repair procedures are available.

551-4.3.5.6.3 Each rotor shaft is supported on a set of ball and roller bearings that is located outboard of the lube oil seals. Each rotor carries an air seal and an oil seal at each end. The two seals face each other with an open space between them, which is vented to atmosphere to prevent leakage across the seals and facilitate seal failure detection. The air and oil seals are of the mechanical shaft seal type and are identical and initially interchangeable. Once in service, interchanging of air and oil seals is not recommended. The air seals are kept cool and lubricated by the injection water in the compressor.

551-4.3.5.6.4 An oil-pump, oil-cooler, and oil-injection nozzles provide the circulating oil to cool and lubricate the oil seals. Figure 551-4-8 and Figure 551-4-9 are sectional elevation views of the compressor. The helical lobes and grooves on the rotors are not shown.

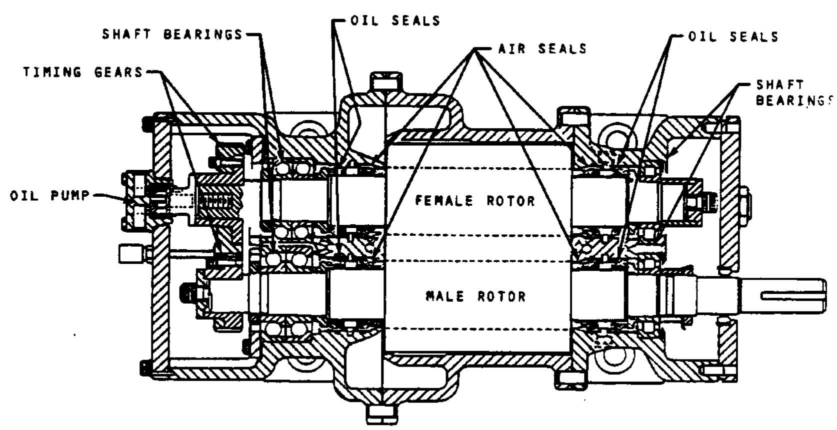


Figure 551-4-8 Sectional Plan View - Helical Screw Compressor

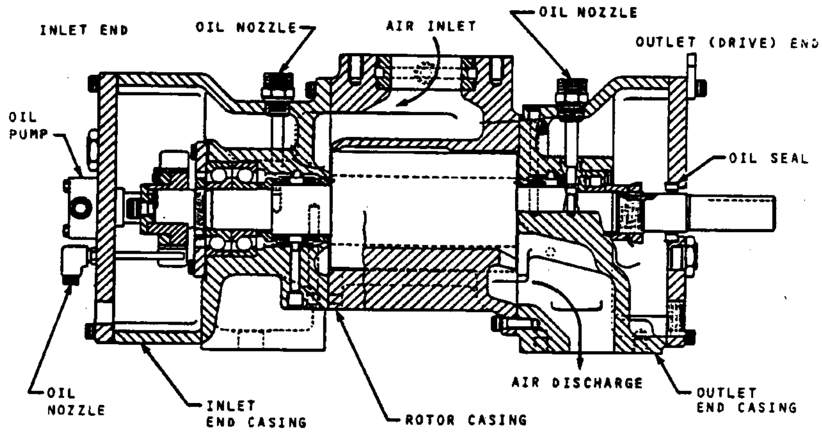


Figure 551-4-9 Sectional View, Elevation - Helical Screw Compressor

551-4.3.5.7 Configuration. The rotary, water-flooded helical screw compressor currently in Navy service is a compact, integrated assembly consisting of the oil-free rotary compressor, a water separator, a refrigerated dryer, a 4-ft^3 receiver, the motor controller, and associated controls. The assembly is shown in Figure 551-4-10. The enumerated components are fully interconnected and mounted on a welded, tubular steel subbase to facilitate installation with or without sound attenuating mounts, as desired (FFG-7, CG-49, LHD-1, and DDG-51 will only have base-mounted compressors). The compressor proper and electric motor are mounted on a separate base, which in turn is mounted on resilient mounts on the assembly subbase. This assures maintaining the critical alignment of the compressor and motor. Flexible piping and cable connection are provided to the compressor proper, motor, and to the entire assembly in conformance with the resilient mounting arrangement.

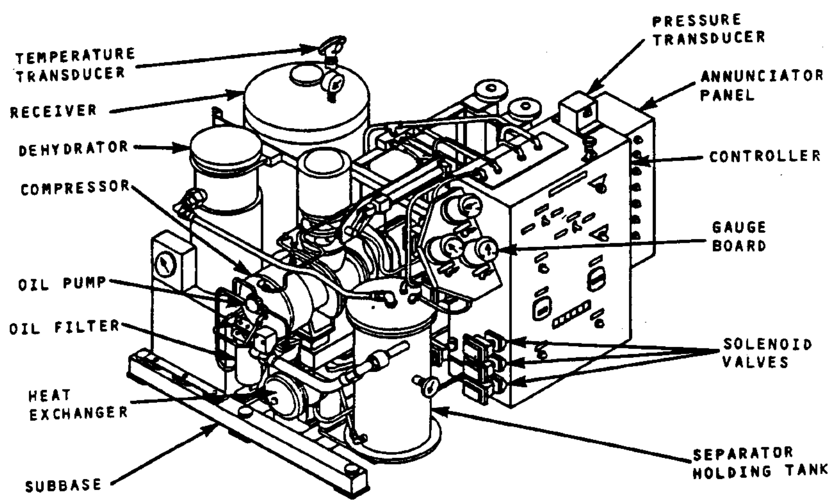


Figure 551-4-10 Oil-Free Rotary Helical Screw Compressor

551-4.3.5.8 Fluid System Design. The fluid system design which provides the functional interrelationship of compressed air, injection water, lubricating oil, and dehydrator is described in the following paragraphs.

551-4.3.5.9 Compressed Air System (see Figure 551-4-11). The line running between the compressor and the separator-holding tank is common to the air system and the injection water system; although the check valve is shown only in the air system diagram. The location of the sensing point of the high dewpoint temperature switch is shown in Figure 551-4-12.

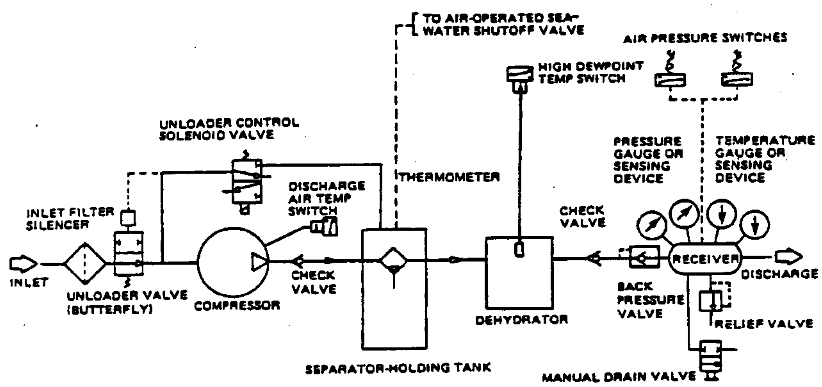


Figure 551-4-11 Airflow Diagram

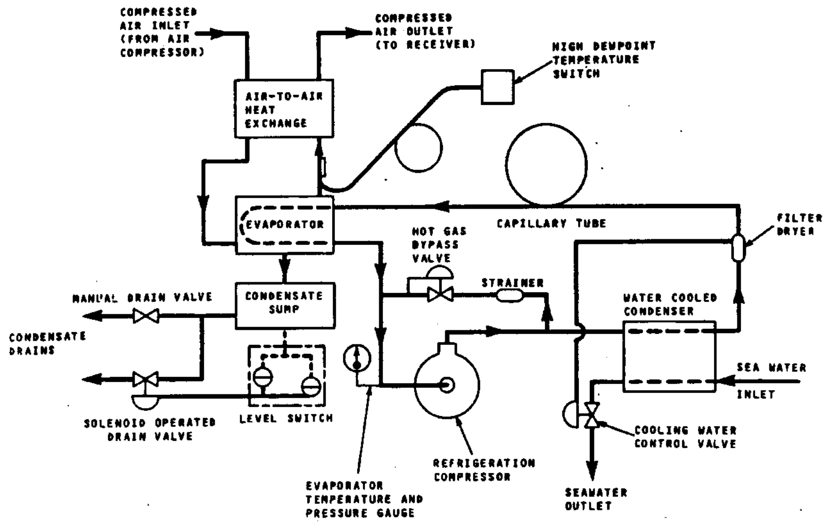


Figure 551-4-12 Flow Diagram of Type I Dehydrator Air and Refrigeration Circuits

551-4.3.5.10 Injection Water System. (see Figure 551-4-13). The injection waterline at the inlet to the compressor terminates in a ring-type injection water manifold at the compressor's suction inlet and does not terminate in the suction line. The injection water solenoid valve is closed except when the compressor motor (and compressor) is running. The water in the separator-holding tank is maintained at the proper level to ensure that injection water is available at all times when the compressor is operating. Under high inlet humidity conditions, the compressed air will give up water to the injection system so that the water level in the holding tank will rise to the point where excess water shall be drained off. Under conditions when the compressor inlet air is at low relative humidity, the injection water system will give up water to the compressed air, causing the water level in the holding tank to fall so that fresh water shall be added to the injection water system. This explains the need for monitoring the holding tank water level and for providing automatic freshwater supply and drain valves for this system.

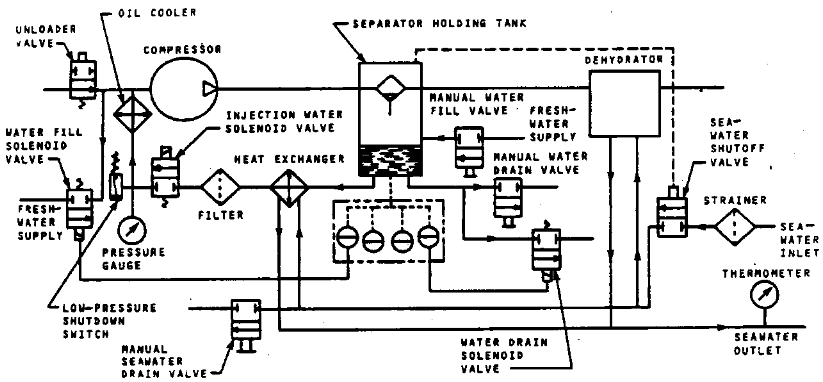


Figure 551-4-13 Injection Water and Seawater Flow Diagram

551-4.3.5.10.1 The conditions of operation when no water needs to be added or drained are obtained when the water content of the compressor intake air equals the water content of the compressed air leaving the separator-holding tank. At the discharge temperature of 110° F, the moisture content of the compressed air leaving the separator is approximately 0.005 pounds of moisture per pounds of dry air. This would be the moisture content of inlet air at 72° F and 30 percent relative humidity. At an air inlet temperature of 72° F and a relative humidity higher than 30 percent, water would be given up by the compressed air and the water level in the holding tank will gradually rise. Because the compressor inlet air usually has a humidity ratio (weight of moisture to weight of dry air) higher than 0.005, water will usually have to be drained from the holding tank. It is of great importance that the high level drain switch and drain valve, and the high level alarm and shutdown switch be maintained operable to prevent flooding of the separator and damage to the compressor.

551-4.3.5.11 Lubricating Oil System (see Figure 551-4-14). This is a closed loop system without breather and filler cap. Oil is added by removing a sight glass plug on the compressor endplate. Only lubricating oil Navy symbol 2190TEP, conforming to MIL-L-17331, shall be used. The manufacturer's recommended oil filter cartridge shall be used. A dipstick oil level indicator and drain valve are provided on the main oil sump. Extraordinary cleanliness precautions should be observed in servicing the lube oil system.

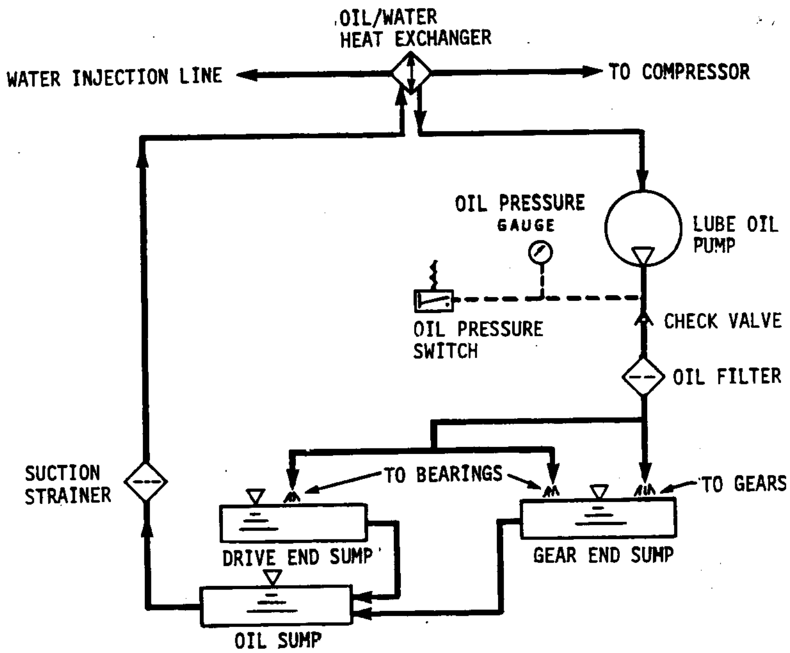


Figure 551-4-14 Lubricating Oil System Flow Diagram

551-4.3.5.12 Type I Dehydrator Flow Diagram. A back pressure valve is provided downstream of the type I (refrigerant) dehydrator as shown in the air system (see Figure 551-4-11). The back pressure valve serves to build up the air pressure as rapidly as possible in the dehydrator and to maintain the elevated pressure. The elevated pressure enables the dryer to be effective in removing moisture from the air. The refrigerated dryer is not able to remove the moisture and attain the required dewpoint when the air pressure falls below 75 lb/in^2 g. The back pressure valve should therefore remain closed until a minimum air pressure of 75 lb/in^2 g has built up in the compressor discharge air piping. A defective back pressure valve is one that opens at a pressure lower than 75 lb/in^2 g. A valve that opens at 80 lb/in^2 g, or somewhat higher, is not defective.

551-4.3.5.12.1 The air-to-air heat exchanger (see Figure 551-4-12) precools the air before it enters the evaporator. This precooling improves the efficiency of the dryer. The fact that air leaving the evaporator is reheated is helpful in preventing external condensation on the downstream air piping and receiver.

551-4.3.5.13 Operating Controls. The rotary compressor has been provided with a control system that permits the compressor to be operated in either manual or automatic control. After the operating mode selector switch has been set to the mode of control desired, the compressor is placed into operation by setting the ON/OFF selector switch to the ON position. More detailed operating procedures are described in the following paragraphs.

551-4.3.5.14 Manual Control. In the manual mode of operation, the compressor is started by pushing the ON/OFF switch to the ON position. The compressor will run and deliver compressed air to the receiver until the desired air pressure in the receiver is reached. This pressure is the cutout setpoint (125 lb/in^2 g) of the control switch. When the cutout pressure is reached, the compressor stops, the injection water solenoid valve closes, and the condensate drain and blowdown solenoid valve opens. The closed injection water valve stops the flow of injection water to the nonoperating compressor. The open condensate drain valve (on the refrigerated dryer) depressurizes the compressor, the separator-holding tank, the air side of the refrigerated dryer, and the interconnecting air piping up to the check valve between the dryer and receiver. The compressor will not restart automatically but may be manually restarted when the receiver pressure has dropped to the cut-in setpoint of the control switch.

551-4.3.5.15 Automatic Control. In the automatic mode of operation, the compressor is under the automatic start and stop control of a pressure switch (control switch) responsive to the receiver air pressure, and a 10-minute timer. The compressor is placed into the automatic mode by setting the operating mode selector switch to any one of a number of automatic control positions, each position representing a control switch with specific preset cut-in and cutout pressure setpoints; for example, 115/125 lb/in^2 g or 110/120 lb/in^2 g.

551-4.3.5.15.1 Once the operating mode selector switch has been set, the compressor is placed under automatic control of the selected pressure switch by pressing the ON position of the ON/OFF switch. The compressor will start and deliver compressed air to the receiver when the receiver pressure falls to, or is less than, the cut-in setpoint pressure of the control switch. When the receiver pressure is equal to the cutout setpoint pressure control switch, the compressor unloads; that is, the compressor continues to run but does not deliver air to the receiver.

551-4.3.5.15.2 If within the next 10 minute period the receiver pressure drops to the cut-in pressure, the compressor reloads; that is, the compressor again delivers compressed air to the receiver. If 10 minutes elapse starting from the instant the compressor is unloaded without receiver pressure falling to the cut-in pressure, the compressor shuts down. The compressor will automatically restart and deliver compressed air when the receiver pressure drops to cut-in pressure. Hence, the cut-in pressure either restarts or reloads the compressor, depending on whether or not the 10-minute timer has shut down the compressor. On the other hand, the cutout pressure only unloads the compressor and starts the 10-minute timer. As in manual control, when the compressor stops, the injection water valve closes and the condensate drain/blowdown valve opens.

551-4.3.5.16 Unloaded Operation. Under automatic control, when the control switch cutout setpoint is reached to unload the compressor, the control system causes the unloader control solenoid valve to open, thereby, recirculating air from the separator-holding tank back to the compressor inlet. The unloader control solenoid valve also allows compressed air to power a pneumatic piston which closes the compressor air supply butterfly valve and holds it closed. This permits only the recirculated air to enter the compressor at a reduced suction pressure so that the air throughflow is reduced somewhat which reduces brake horsepower. Recirculation of the discharge air also reduces the discharge pressure so that air is no longer delivered to the receiver.

551-4.3.5.16.1 Failure of the unloader control solenoid valve to open or to stay open, and the air supply butterfly valve (unloader valve) to close and stay closed will cause the relief valve on the receiver to lift. During unloaded operation, the compressor discharge pressure is held sufficiently high by the built-in restriction of the air recirculating system to cause some injection waterflow to maintain the compressor and recirculating air at a satisfactory temperature.

551-4.3.5.16.2 Automatic compressor operation with the unloading feature permits relatively short load/unload cycle operation with a more constant air supply pressure in the compressed air system without use of a large air receiver. Start-stop cycling of the compressor motor, in place of unloading, would require a substantially larger air receiver to prevent short-cycling and overheating of the electric motor. The refrigerated dryer does not shut down during unloaded air compressor operation but similarly also unloads by means of the hot gas bypass valve. This valve functions automatically by sensing evaporator pressure and allows hot gas to be recirculated when there is no compressed airflow (no cooling load) over the evaporator cooling coils.

551-4.3.5.17 Emergency Shutdown Protection. The rotary compressor has been provided with the necessary automatic emergency shutdown features and emergency shutdown alarms to protect the compressor from major damage, failure, or interruption of supporting systems and components. The name of the shutdown device usually describes the abnormal symptom that it monitors. It is important that the operator be thoroughly familiar with the meaning of each potential failure symptom so that the deficiency can be quickly corrected. The troubleshooting instructions contained in the manufacturer's technical manual should be consulted. Emergency shutdown devices and annunciator indicating lamps are provided for the following failure symptoms:

a. High air temperature, compressor discharge

b. High air temperature, air dryer evaporator discharge (dewpoint temperature); failure to attain dewpoint temperature at the evaporator 2 minutes after compressor startup

c. Low lubricating oil pressure; failure to attain lube oil pressure 12 to 15 seconds after compressor startup

d. Low injection water pressure; failure to attain injection water pressure 12 to 15 seconds after compressor startup

e. High injection water level in separator-holding tank (3 to 5 seconds self-correction time delay)

f. Low injection water level in separator-holding tank (3 to 5 seconds self-correction time delay)

g. High condensate level in dehydrator condensate sump.

551-4.3.5.18 Service Considerations. Rotary helical screw compressors are precision machines which depend on absolute cleanliness in servicing and on careful adherence to the manufacturer's instructions for maintenance and repair. Successful compressor operation requires that each operator have a thorough knowledge of the construction and configuration of the compressor and its components, the function that each component performs, a thorough insight into the design of the various systems, the interrelation and interaction of these systems, and complete familiarity with and understanding of the protective monitor and automatic controls. This information is contained in the preceding paragraphs. More detailed specific information can be found in the manufacturer's technical manual. Specific service considerations are described in the following paragraphs.

551-4.3.5.19 Concerns Before Starting. The practices and precautions that should be observed before starting are generally those that are discussed and enumerated in paragraphs 551-4.2.22.1 through 551-4.2.22.1.3. Important specific precautions and preoperation checks which should be observed are contained in the manufacturer's manual for the compressors.

551-4.3.5.20 Concerns During Operation. The successful operation of the water-flooded helical screw compressor depends in great measure on the proper functioning of automatic devices which monitor the critical performance parameters, such as air discharge temperature, dewpoint temperature, injection water pressure, injection water level, and lubricating oil pressure and level. It should be the compressor operator's foremost concern that the automatic monitoring devices are functionally operative. This requires regular verification checks according to the manufacturer's instruction. Regular periodic observation by a compressor operator should be directed to:

a. The oil, air, and injection water filters

b. Oil, injection water, and condensate levels in the applicable tanks and sumps

c. Interseal area leakoff

d. Performance of the condensate blowdown valve, the back pressure valve, and the condensate sump and injection water tank level controls

e. Indicating light and audible alarm functioning

f. Seating of check valves and automatic supply and drain valves

g. Tightness of fluid piping connections, protective covers, and mounting bolts, and the general performance of the compressor with respect to vibration, noise, and pressure and temperature profiles.

551-4.3.5.20.1 A written record or log should be made of abnormalities, whether corrected or not, and suspected abnormalities or changes in performance as encountered and observed by the operator at each regular inspection. Included in the operating log should be pressure, temperature, and operating time meter readings (loaded operation and running time) for the various pressure gauges, temperature indicators, and hour meters provided with the compressor. These records may be discarded after compressor overhaul or when their usefulness for fault diagnosis and performance evaluation is no longer valid.

551-4.3.5.21 Preventive and Corrective Maintenance. This aspect of compressor service is most authoritatively covered by the validated and approved procedures of the PMS and instructions contained in the manufacturer's technical manual.

551-4.3.5.22 Deactivation and Preservation. The manufacturer's recommendations as contained in the technical manual for the specific compressor should be followed. For indefinite deactivation, the seawater and injection water systems, including all components coming into contact with seawater and fresh water during normal compressor operation, shall be drained, flushed, and dried with warm low-pressure air. All areas and components in these systems where water may be trapped should be given special consideration to find a suitable technique to dislodge the water and moisture, such as tilting the compressor, opening of vents, operating the device while blowing dry air, or partially disassembling and reassembling. If the compressor is deactivated for repair, the restoration to service should be scheduled as early as possible.

551-4.3.6 NASH WATER-RING AIR COMPRESSORS. These positive displacement rotary compressors deliver water-pumped oil-free compressed air up to a pressure of 125 lb/in^2 g. They are a well known design described in most textbooks on compressed air and have been given many names. The compressors were developed and have been manufactured for many years in several different versions by only one company in the United States: the Nash Engineering Company. The compressors are, therefore, usually named and recognized as the Nash water-ring compressors. In Navy shipboard service, the Nash compressors are used as priming pumps (vacuum pumps) for condensate pump priming, and as oil-free compressors for pneumatic controls and LP ships' service, principally on submarines. The submarine compressors are furnished in two small sizes: 15 scfm at 85 lb/in^2 g for pneumatic controls, and 40 scfm at 125 lb/in^2 g for ships' service. On Navy surface ships, the Nash compressors have been largely replaced by large capacity reciprocating and centrifugal compressors.

551-4.3.6.1 Operating Principle. The operating principle is best explained by use of Figure 551-4-15. A radially compartmented rotor or bucketwheel rotates within an elliptically-shaped housing or lobe. The lobe is partially filled with water. The amount of water is controlled and held constant. Rotation of the rotor causes the water to be swirled within the lobe. The water in swirling motion, rotating with the rotor, is held against the outer periphery within the lobe by centrifugal force and forms a rotating water-ring which takes on the elliptical shape of the lobe. Because the rotor is truly round, whereas the water-ring is elliptical, the water is forced to enter the rotor chambers of the narrow axis and to move out of the chamber at the long axis of the ellipse. In this manner the water acts as a piston in each chamber.

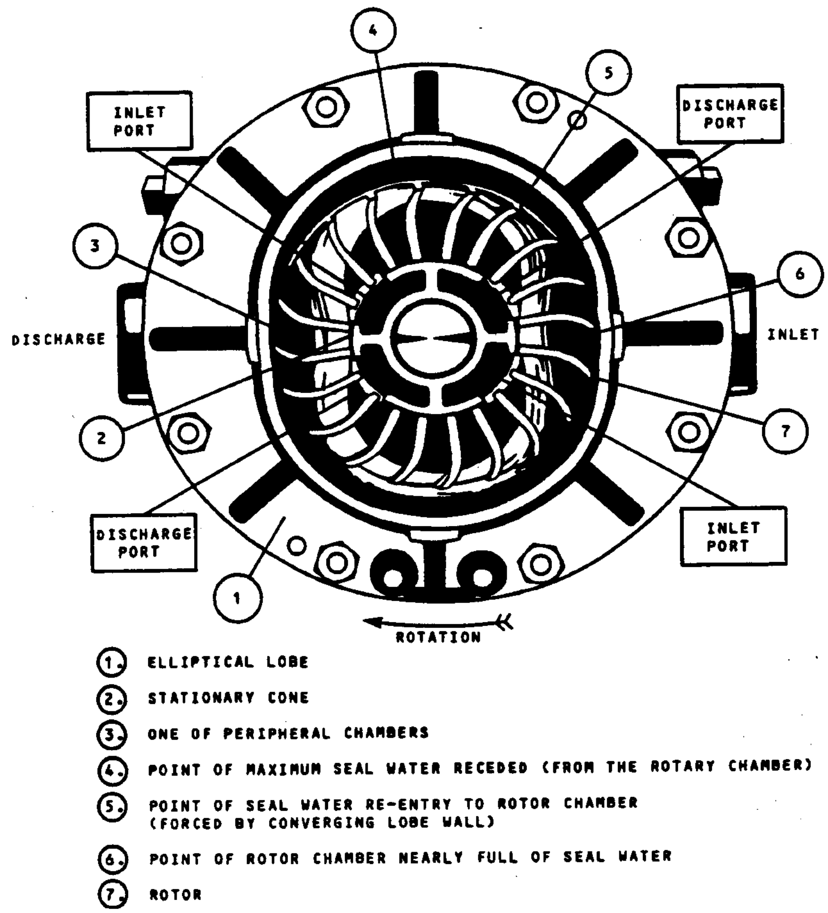


Figure 551-4-15 Typical Water-Ring Rotary Compressor

551-4.3.6.1.1 The rotor rotates on a stationary cone with a nonrubbing close clearance between the rotor and cone. Ports are located in the inner-circumference of the rotor at the bottom of each bucket. Two pairs of ports (a suction port and discharge port) are provided, opposite to each other, in the stationary cone. The location of the suction and discharge ports is phased with respect to the position of the elliptical housing and the rotating speed of the rotor. This is so that the ports of the rotating buckets pass over and communicate with the suction and discharge ports of the stationary cone as the water performs the suction and compression strokes (twice per revolution).

551-4.3.6.1.2 The rotor is mounted on the extended electric motor shaft in cantilever fashion. A mechanical shaft seal is provided at the shaft to lobe entrance. The electric motor bearings are designed to serve both the motor and the compressor. No other bearings are provided.

551-4.3.6.1.3 The opposite end of the lobe is closed by the compressor head, on which is mounted the stationary cone. The air and water mixture discharge port is in the head, as are the air inlet connection and main circulating water connections. The water cooler is mounted separate from the compressor, utilizing flexible hose.

551-4.3.6.1.4 An alternate version of this design uses a circular lobe. The rotor is located eccentrically within the lobe. In this arrangement, only one suction stroke and one discharge stroke occur per revolution.

551-4.3.6.2 Air System. The air enters the compressor by way of a filter-silencer. It is compressed and exits from the compressor as a water and air mixture. The mixture passes through the discharge silencer into a water separator where the water separates by gravity and from which water-free air is discharged, by way of a check valve to the ships air receiver or an air dryer. The air, though free of water, is saturated with water vapor, as is the case when compressed air is discharged from any type of compressor. The amount of moisture remaining in the air is a function of the compressed air temperature and may be reduced by additional cooling with use of an aftercooler or refrigerated dryer. An automatic air pressure relief valve, installed in a bypass between the compressor discharge and compressor inlet, prevents the compressor discharge pressure (that is, the compressor back pressure) from exceeding a preset maximum limit. For a system having a 125 lb/in^2 nominal operating pressure, the maximum limit is approximately 127 lb/in^2 g.

551-4.3.6.3 Freshwater System. Fresh water is the compressing element in the compression chambers of the rotor. In addition to this primary function, the water absorbs the heat of compression. A third critical function of the water is to seal the clearance space between the rotor and the stationary cone to prevent air blowby and maintain good efficiency. To perform these functions, it is necessary that the water be continuously recirculated and cooled, and that it be free of foreign and abrasive material.

551-4.3.6.3.1 The water that is rotating within the compressor housing or lobe shall be of a constant and sufficient amount so that it can fully displace the air in the chamber. The water level in the separator shall be maintained at a proper level so that the differential air pressure can initially prime the compressor and maintain adequate water circulation during operation. A constant quantity of water discharges from the compressor lobe in mixture with the compressed air. The water collects in the separator which acts also as the circulating water reservoir. From the separator the water flows through a seawater cooled heat exchanger and reenters the compressor at the cone seal water connection and the lobe makeup water connection. The cone seal water is metered by a flow-control valve to maintain a constant rate of flow for sealing the cone-to-rotor clearance.

551-4.3.6.3.2 The energy of motion, imparted to the water within the lobe by the rotor, does the work of compression. If the work of compression exceeds the energy of motion of the water, the rotating water-ring stalls or disintegrates. Such a condition will occur, for example, when the air discharge pressure is allowed to exceed the design or maximum operating limit. To prevent water-ring stall, a stall pressure switch senses water-ring pressure at a critical sensing point. Closing of the pressure switch deenergizes a solenoid valve in the air bypass line and relieves the high air discharge pressure, thereby allowing the compressor to recover from the stall condition.

551-4.3.6.4 Operating Controls. The Nash compressor is usually provided with manual control. The compressor is started by the operator and is allowed to operate until no longer required. The discharge air bypass valve automatically bypasses the compressed air to the compressor inlet when the compressor output exceeds the demand of the LP air system.

551-4.3.6.4.1 Automatic operation may be provided. The principal elements of an automatic control system are an electric or pneumatic unloading valve such as the solenoid bypass valve, and a load/unload air pressure switch. The automatic controls and principles of operation are similar to those described for the waterflooded helical screw rotary compressors. A time switch should be provided to shut off the compressor to avoid prolonged unloaded operation. Restarting of the compressor is done by the load/unload pressure switch. A sufficiently large air receiver shall be provided for automatic operation to prevent cycling of the compressor.

551-4.3.6.5 Service Considerations. The Nash water-ring compressor is a reliable, self-sufficient machine that is easy to operate once it has been initially adjusted. A few observations at regular intervals are advisable, as follows:

a. On initial startup, it should be ascertained that the compressor's rotation is in the direction indicated on the electric motor.

b. The rotor should rotate freely without rubbing or interference when rotated manually.

c. When the compressor has been primed with clean water and is operating, the automatic drain valve in the water overflow line from the separator should not allow compressed air to escape.

d. The seal water strainer in the water return line from the cooler should not impose an undue restriction to flow. It should be cleaned regularly.

e. The water level in the separator reservoir should be observed and maintained at the proper level. It should be understood that the water level may rise, requiring drainoff, due to high humidity inlet air conditions. At other times the water level will fall, and makeup water shall be added at the funnel. The loss of water will be due to the fact that the inlet air during the preceding operating period was very dry, so that the air has taken on water vapor in the compressor. These changes in compressor behavior, with respect to water level, are therefore normal and should be no cause for alarm. However, it is necessary that the water level be maintained within the range indicated on the sight glass.

f. An early indication of deterioration in performance will be a deviation of air and water operating temperatures and pressures from those indicated in the compressor manual. A record of prevailing operating temperatures and pressures will be helpful as a means of evaluating performance and detecting maintenance requirements.

g. When higher than normal temperatures are being experienced, the fault isolation procedure shall follow a sequence as follows:

   1 The cooling water supply to the heat exchanger

   2 Cleanliness condition of the air inlet filter-silencer

   3 Obstruction in air inlet piping

   4 Accuracy of the temperature indicators

   5 Binding and mechanical interference in the rotor to cone and rotor-to-lobe running clearances.

h. When abnormal air pressures are being experienced, the fault isolation may proceed as follows:

   1 Calibration of the pressure gauge

   2 Condition of inlet filter-silencer

   3 Air leakage through separator water overflow valve or trap

   4 Level of seal water in separator

   5 Solenoid air bypass valve or related pressure switch performance

   6 Automatic air bypass valve performance.

i. The electric motor bearings maintain the concentric alignment of the rotor and stationary cone clearance. Bearing wear will be the most likely cause of rubbing of the rotor. Protection of the motor bearings from grit, and regular attention to lubrication of these bearings is critical to long compressor life.

j. The rotor to cone clearance, which is critical to efficient performance and quiet operation, is set by means of shims at the mounting flange between the motor and the compressor lobe (housing). It is important that the thickness of these shims be properly selected in the event the compressor is disassembled and reassembled.

k. The compressor should not be exposed to freezing temperatures unless it is continuously operating without interruption, or unless all components and piping are fully drained and free of water. The manufacturer's manual should be consulted for the procedure to be followed.

551-4.3.6.6 Preservation with Power Available. When the compressor is indefinitely secured but ambient temperatures will not approach freezing and electric power connections and power supply can be maintained, the compressor will be adequately preserved if operated for a short period of not less than 3 minutes once every day. During this operating period, full circulation of seal water and cooling water shall be assured. During the secured period with daily operation, the compressor should be protected, with adequate cover, from the weather and from dust and industrial debris.

551-4.3.6.7 Preservation at Freezing Temperature. If the compressor is indefinitely secured when ambient temperatures will be near or below freezing, it is mandatory that the compressor, the remotely installed heat exchanger, and all piping be thoroughly flushed, drained, and dried, externally and internally. The thoroughness of this procedure cannot be overemphasized and should be accomplished according to the instructions contained in the manufacturer's manual. Draining, drying, and cleaning where necessary should be followed by wrapping or covering the compressor for protection from the weather, dust, and debris commensurate with the conditions and length of storage.

551-4.3.7 CENTRIFUGAL COMPRESSORS. Centrifugal ships' service air compressors were introduced into the fleet to meet the high capacity, oil-free, LP compressed air demands of new large ships such as aircraft carriers. The compressors have a nominal capacity of 1,250 ft^3 of free air per minute when operating at a discharge pressure of 125 lb/in^2 g. The ships' service air compressors are driven by 350-horsepower, constant speed, electric motors.

551-4.3.7.1 Usage of Centrifugal Compressors. Centrifugal compressors are used in place of a multiplicity of smaller reciprocating compressors not only because of savings in weight, space, and anticipated lower maintenance cost, but also because a high capacity centrifugal compressor is more responsive to an intermittent, or a sustained, high air demand. The successful application of centrifugal compressors for LP ships' service air systems also made possible the introduction of LP O_2 N_2 producer plants onboard Navy ships. LP centrifugal compressors are fully interchangeable for O_2 N_2 producer service and LP compressed air system service, provided compatible discharge pressure and capacity requirements were imposed during ship design. The description of the ships' service centrifugal compressors herein, therefore, also applies to the LP O_2 N_2 producer plant compressors, although the capacity, discharge pressure, and horsepower may be different for some O_2 N_2 producer applications.

551-4.3.7.2 Variations in Basic Design. The use of centrifugal compressors for LP ships' service air systems is based on many years of similar air system service in industrial plants. Two types of centrifugal air compressors with essentially identical performance characteristics are in use as described in the following paragraphs.

551-4.3.7.2.1 Multistage, Single-Shaft Design. In this type of centrifugal air compressor, several impellers are installed side by side on a common shaft. The impellers rotate in the manner of a rotor. Dividing walls, called diaphragms, with interstage shaft seals provide separation between the impellers so that each can operate independently of the other, although they rotate at equal rpm on the same shaft. The shaft speed is approximately 39,000 rpm. The relatively long shaft span with inherent flexibility requires special care during design. Only a small number of three-stage units of this design are in service in the fleet.

551-4.3.7.2.2 Multistage, Multishaft Design. This air compressor design incorporates a drive system by which the several individual compression stage impellers are each driven on a separate shaft at optimum speed for maximum performance of each stage. This is accomplished by use of a bullgear which simultaneously drives the several pinion gears that are individually sized to give the desired speed for the specific impeller. In providing speed selection for individual impellers, the designer is given greater latitude in matching impeller performance, a difficult task when all impellers operate at the same rpm. It has the advantage of providing a much wider range of service application for a compressor, and permits changes in the number of stages. The end result is greater standardization and lower manufacturing costs. Typical shaft speeds for the three stages are: 32,088 rpm, first stage; 43,854 rpm, second stage; and 52,624 rpm, third stage. This design will be described later since most of the installed centrifugal compressors are of this type.

551-4.3.7.3 Configuration. Centrifugal air compressors, driven by 350 to 450 horsepower electric motors with impeller speeds up to 52,000 rpm, and operating continuously under essentially automatic control, are fairly complex machinery plants. Figure 551-4-16 and Figure 551-4-17 show the compressor unit (uninstalled) in outline without attached piping and without the aftercooling equipment.

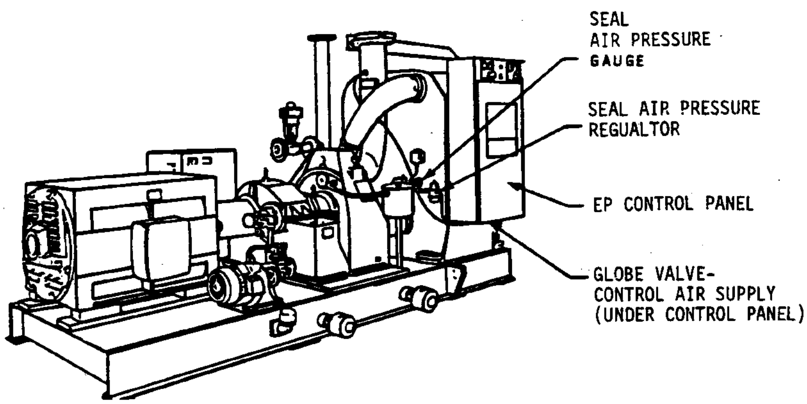


Figure 551-4-16 Location of Operator Controls

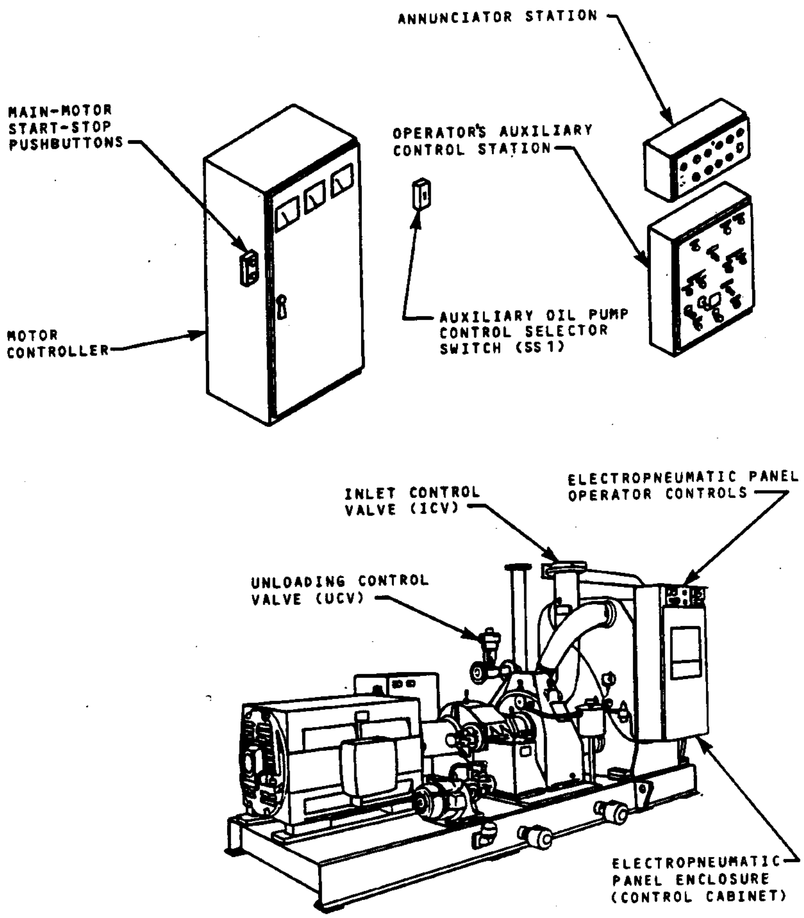


Figure 551-4-17 Location of Operator Controls - F, H, J, and L Configurations

551-4.3.7.3.1 Figure 551-4-18 is an exploded view of the compressor unit, more clearly identifying the several major components, namely the main electric motor, the speed increasing gear assembly, the compressor drive assembly with the centrifugal compression elements (impellers, diffusers, and volutes), and the intercooler assembly. An additional separately installed aftercooler, a chiller and separator assembly are not shown. The electropneumatic controls are arranged in a special panel mounted on the intercooler housing.

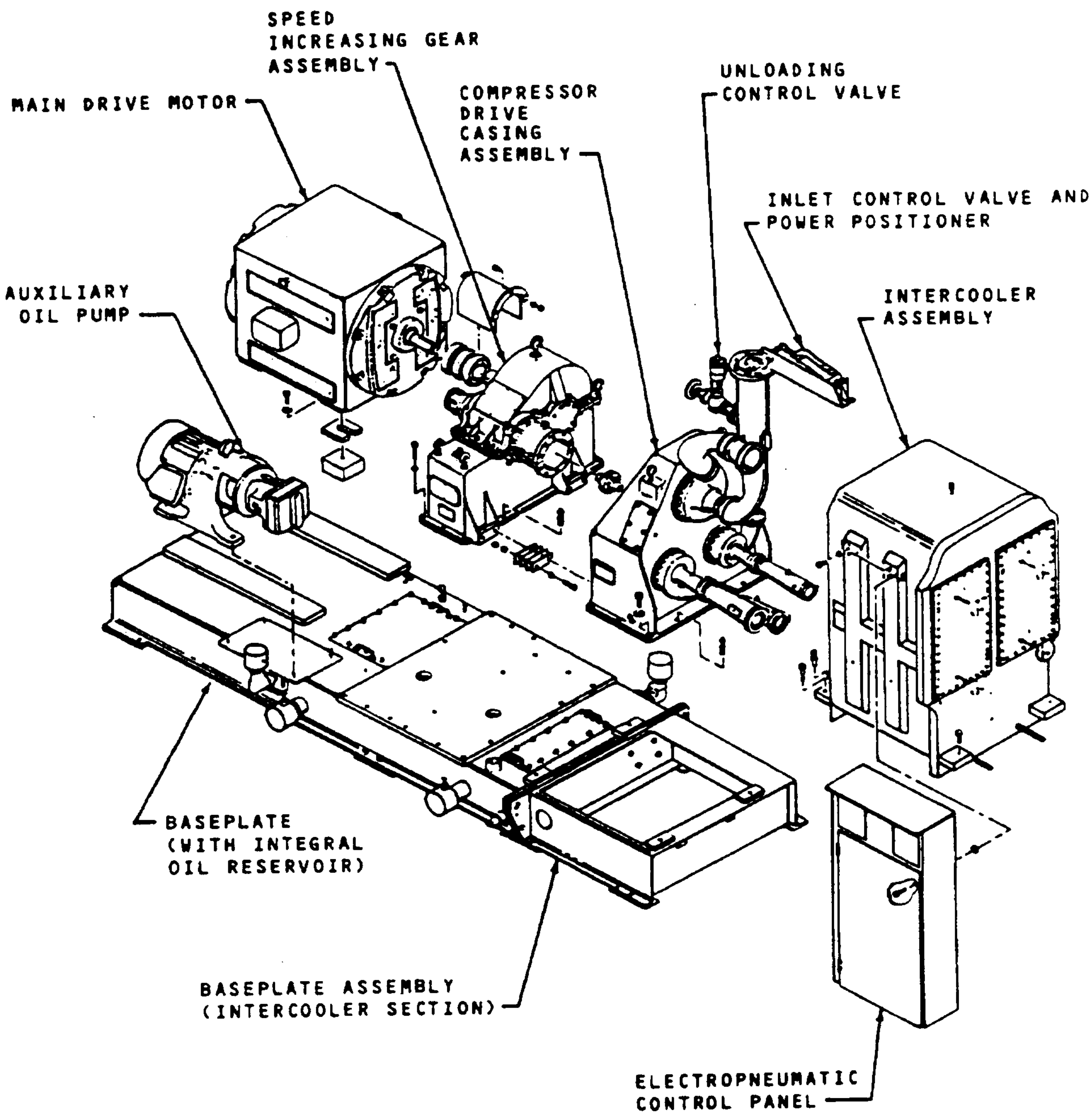


Figure 551-4-18 Relationship of the Compressor and Components

551-4.3.7.3.2 A schematic presentation of the drive system indicates that in addition to the speed increasing gear assembly with its bullgear operating at electric motor speed, the compressor drive assembly incorporates a second bullgear which drives the three individual impeller pinion gears at the required impeller rpm (see Figure 551-4-19). Were the compressor drive assembly to be driven by a steam turbine, the speed increasing gear assembly would not be required.

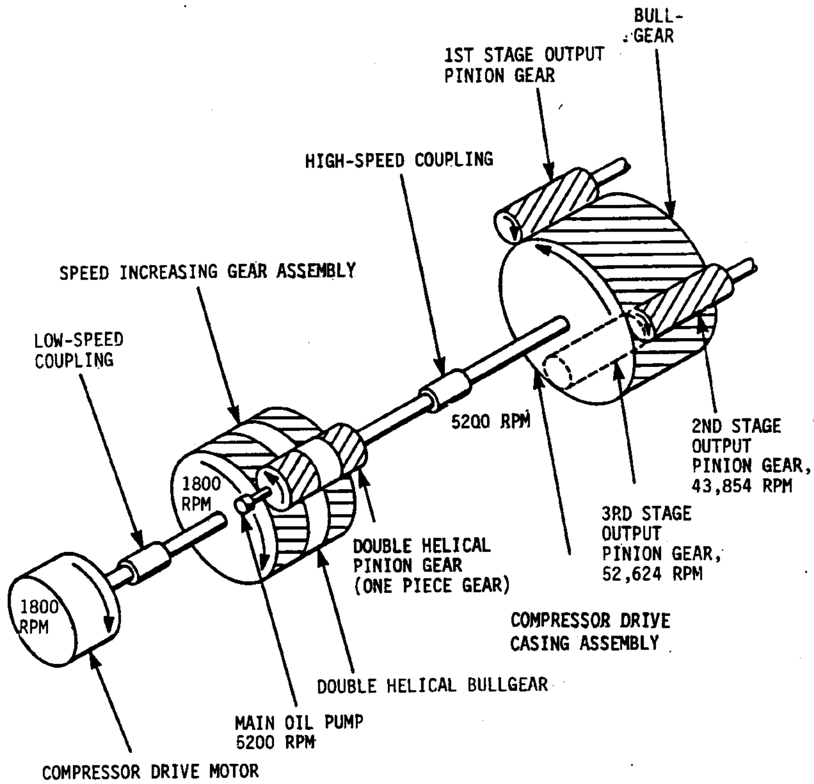
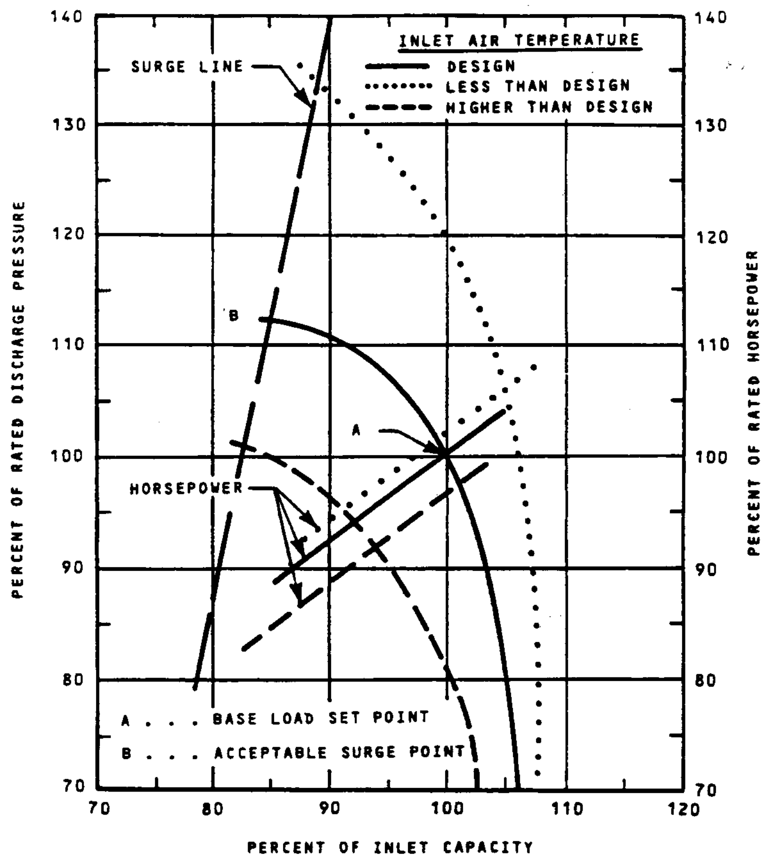


Figure 551-4-19 Compressor Drive System Schematic Diagram

551-4.3.7.3.3 The compressed air discharged from the last stage is lead through a two-element shell and tube type aftercooler, employing seawater as cooling medium, usually followed by an additional aftercooler or chiller which employs chilled fresh water from the ships' air-conditioning chilled water system for cooling of the compressed air to a final temperature of 60° F (which is also the dewpoint). In viewing the compressor unit as an assembly, the several component elements in which the actual compression takes place are very much obscured because they are relatively small.

551-4.3.7.4 Air System. Figure 551-4-20 is an airflow diagram of the air system for the centrifugal ships' service air compressor. The temperatures and pressures indicated are typical for a 1,250 ft^3 compressor operating in base mode (see paragraph 551-4.3.7.8) at an inlet temperature of 85° F and a discharge pressure of 125 lb/in^2 g. Output flow not utilized in the ships' compressed air system is blown off by the Unloading Control Valve (UCV). Most installations incorporate only the first UCV at the third-stage discharge ahead of the aftercooler. This location of the first UCV is necessary, even though hot air is discharged, to provide direct blowoff for the prevention of compressor surge.



THE THREE CURVES ABOVE COMPARE OPERATING CHARACTERISTICS WITH PRESSURE AND FLOW, INCLUDING CHANGES IN SURGE POINT AND HORSEPOWER REQUIREMENTS WITHOUT A CONTROLLING DEVICE IN THE INLET AND DISCHARGE PIPING.

Figure 551-4-20 Typical Performance Curve

551-4.3.7.5 Basic Principles of Air System Operation. Air enters the combination inlet filter and silencer (see Figure 551-4-21) where it will experience an initial small pressure drop. The air then flows by way of a properly proportioned inlet nozzle into the eye of the first-stage impeller. The high-speed impeller, by centrifugal action, imparts a high velocity to the air. The velocity energy is converted to static pressure in the diffuser element of the first compression stage. A volute-shaped casing surrounding the diffuser provides additional conversion from velocity to static pressure as it collects the air from the diffuser and directs it through the discharge nozzle to the first-stage cooler (intercooler).

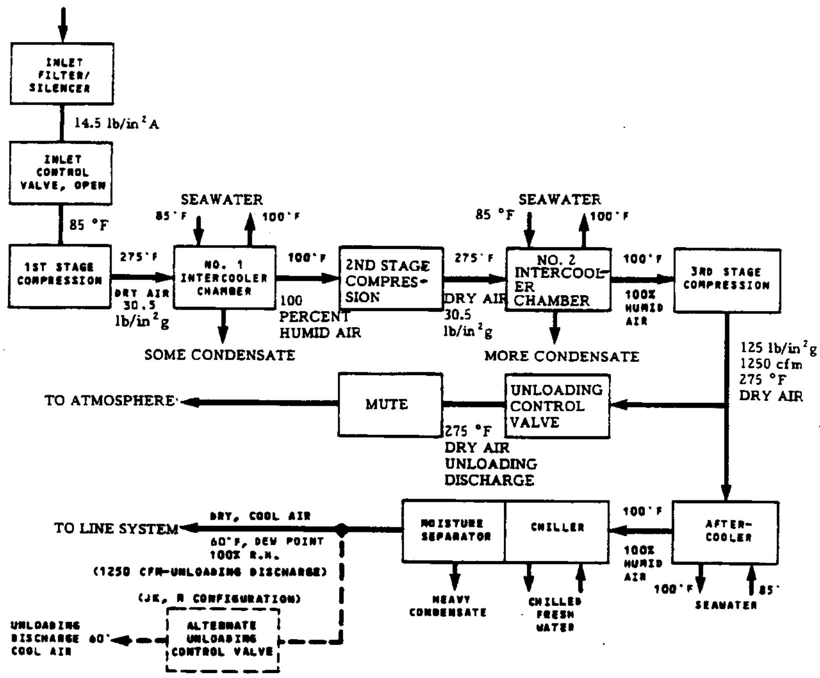


Figure 551-4-21 Flow Diagram for 1,250 cfm, 125 lb/in^2 g Compressor

551-4.3.7.5.1 After passing through the cooler, where some moisture may be condensed and precipitated (depending on atmospheric air inlet conditions), the compressed air passes in succession through the second and third compression stages in similar manner. The density of the inlet air, the diameter and rotational speed of the impeller, the shape of impeller blades, and the design of the diffuser and volute determine the pressure rise that is obtained in each stage. Three compression stages, with proper intercooling between stages, are required to reach a pressure of 125 lb/in^2 g.

551-4.3.7.5.2 Because each stage design is based on a specific density of the air entering the eye of the impeller, it is important that both the first- and secondstage intercoolers perform their cooling function as required. If intercooling is not as specified (a temperature reduction of approximately 180° F in each intercooler), the air inlet density to the second- and third-stage impellers will not be sufficient to achieve the required discharge pressure. An apparently satisfactory temperature rise of the cooling water flowing through the intercooler is not in itself an indication of adequate cooling because cooling water flow may be restricted due to clogged tubes. Insufficient cooling is most likely caused by insufficient water flow. Inadequate cooling in the first-stage intercooler will have a more severe effect on discharge pressure because it is compounded by the compression ratio of the second- and third-stages.

551-4.3.7.5.3 The moisture that is condensed in the intercoolers shall be removed and not allowed to be entrained in the compressed air and carried into the second- and third-stages. Water carryover into the impeller will cause rapid and severe erosion of the impeller blades at the impeller inlet. Foreign solid particles, such as rust flakes, are equally as detrimental.

551-4.3.7.5.4 When two or three compressors are operated alternately so that one or two compressors are temporarily shut down, the line check valves in the discharge piping of the nonoperating compressors shall function properly to prevent compressed air from the system leaking back to the nonoperating compressor and drive its impellers in reverse. Reverse rotation of a compressor may damage the main lube oil pump drive and will damage pinion bearings and seals from lack of lubrication and thrust reversal. Malfunctioning check valves are an all too common occurrence. Hence, special attention shall be given to their performance and care. On some multiple compressor installations, compressed air backflow is prevented by an automatic discharge securing valve which is operated and controlled by the electropneumatic control system. This valve performs the function of a check valve, although a regular check valve is provided as a backup.

551-4.3.7.6 Lubricating System. The special lubricant, Navy symbol 2075 TH conforming to MIL-L-17672 (viscosity 140 SSU at 100° F) recommended by the manufacturer, shall be used in these centrifugal compressors principally to provide proper lubrication to the high-speed pinion bearings. A schematic of the lubricating system is shown in Figure 551-4-22. The system essentially consists of a main oil pump driven from a speed increasing gear pinion, an auxiliary electric motor driven pump for compressor startup and coastdown, an oil cooler, a single or duplex filter system, an oil reservoir located in the base plate of the compressor, and the necessary instruments and control devices. Two electric immersion-type oil heaters with thermostat control preheat the lube oil and maintain it at approximately 70° F to 75° F.

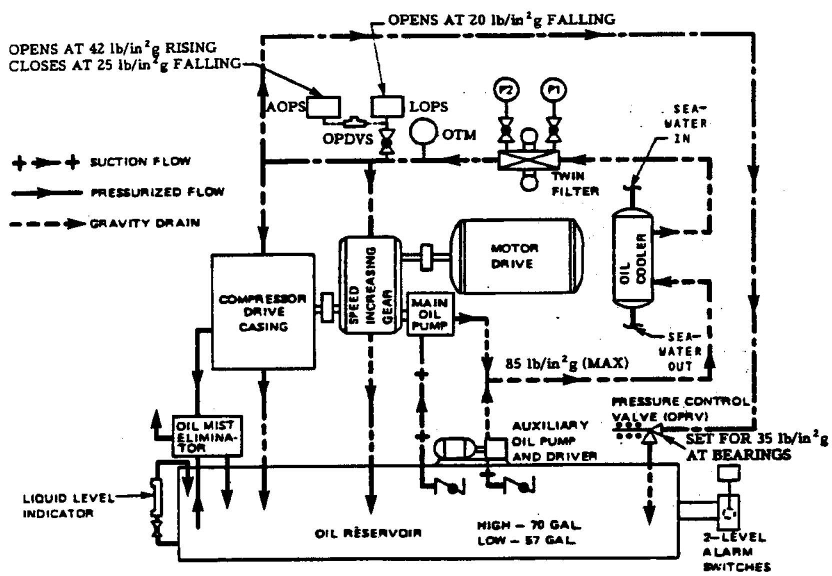


Figure 551-4-22 Lubricating System Schematic

551-4.3.7.6.1 When a compressor is in standby, the auxiliary oil pump is energized before compressor startup. An auxiliary oil pump pressure switch shuts off the pump at a rising pressure setpoint when the main oil pump has reached speed and is maintaining pressure. When the oil pressure falls to within 5 lb/in^2 of the setting of the low oil pressure switch, the auxiliary pump restarts to restore oil pressure if possible. The low oil pressure switch and a high oil temperature switch shut down the compressors on loss of lube oil pressure and at an excessively high oil temperature. The high oil temperature switch includes a preshutdown alarm. An oil pressure delay valve prevents tripout of the auxiliary pump on initial startup when the lube oil has not been sufficiently heated. A lube oil mist eliminator is provided to subdue the oil mist generated in the gear assemblies.

551-4.3.7.7 Seal Air System. This system provides a flow of clean air at 12 to 18 lb/in^2 g pressure to the carbon seals on the high-speed pinion shafts between the outboard bearing and the impeller. As the name implies, the purpose is to assist the carbon seals in preventing leakage of oil mist from the compressor drive casing into the process air during compressor startup and coast-down, and during unloaded operation. The seal air is initially provided from the pneumatic control air serving the electropneumatic control system. A pressure switch in the seal air supply to the carbon seals prevents auxiliary lube oil pump startup unless seal air pressure has been established.

551-4.3.7.7.1 The cleanliness and dryness of the seal air, and pneumatic control air is vital to the satisfactory performance of the centrifugal compressors. For this reason, care shall be exercised to ensure that the control air filters and water separators are functioning, that they are regularly serviced, and that they are adequate for this service. Great care should be given to the initial supply or source of control air at compressor startup. Water accumulation in unused air supply lines is a common fault that should be anticipated and corrected before compressor startup.

551-4.3.7.8 Performance Characteristics. Satisfactory service of centrifugal air compressors onboard ship depends in great measure on the proper understanding of the inherent performance characteristics of these compressors because this understanding is a prerequisite for adjusting, operating, and maintaining the control system. The control system is the operating brain of the centrifugal compressors serving air systems where the air requirements undergo wide swings in usage and where power consumption is critical. The performance characteristics of centrifugal compressors differ from those of positive displacement compressors in that discharge pressure affects the flow capacity of centrifugal compressors, and there are high discharge pressure limits (which vary with inlet conditions) which shall not be exceeded.

551-4.3.7.8.1 Pumping Limit of Centrifugal Compressors. This is best understood if one first reviews the performance characteristics of a positive displacement compressor. The amount of air that a positive displacement compressor delivers is not appreciably affected by changes in discharge pressure. If one were to attempt to choke off a positive displacement compressor at the discharge, the compressor would continue to take in and deliver the same amount of air but with rapid discharge pressure buildup to accommodate and overcome the flow restriction.

551-4.3.7.8.2 When a centrifugal compressor is similarly choked, there will also be some increase in discharge pressure, but there will be a simultaneous reduction in the amount of air the compressor takes in and delivers. It will take only a choking effect equivalent to a 12 to 15 percent rise in rated discharge pressure to disrupt and stop the airflow through the compressor. The pressure above nominal operating pressure (design operating pressure) at which the centrifugal compressor no longer delivers air is called the pumping limit.

551-4.3.7.8.3 Centrifugal compressors are provided with automatic operating controls so that the compressor will not be caused to operate at the pumping limit. Without the controls, the pumping limit would be quickly reached when the compressed airflow is not fully used. When operating at the pumping limit, the compressor is said to be operating in the unstable region of its performance curve plot because its performance is unstable, not smooth and steady. This unstable performance is characterized by audible panting and surging of the airflow, and under some conditions with attendant vibration and shaking of the compressor. When this condition occurs, the compressor is said to be in surge.

551-4.3.7.8.4 Operation in surge can cause compressor damage depending on how severe the surging is. Operation even with only mild surging should be avoided. The pumping limit or surge point (these are synonymous terms) is a unique characteristic of a centrifugal compressor. The compressor is designed to operate at a discharge pressure sufficiently lower than the surge point so that operation in surge can be easily avoided. However, the surge point (discharge pressure at which surging initiates) shifts to a higher or lower pressure when the compressor speed is changed and when the air inlet pressure and inlet temperature change.

551-4.3.7.8.5 Since shipboard centrifugal compressors are constant speed machines, the effects of speed changes may be disregarded. However, the air inlet temperature onboard ship will change, and a clogged air inlet filter will lower the suction pressure.

551-4.3.7.8.6 Assume that for a 125 lb/in^2 g discharge pressure, the surge point is 140 lb/in^2 g at a design air inlet temperature of 90° F and a suction pressure of 14.5 lb/in^2 (clean suction filter in place). When the air inlet temperature rises above 90° F, the surge point will be lowered; that is, the compressor will begin to surge at a lower pressure than 140 lb/in^2 g; therefore, the margin between nominal operating pressure and surge is reduced. When the air inlet temperature drops below 90° F, the surge point will be higher than 140 lb/in^2 g.

551-4.3.7.8.7 A decrease of suction pressure will have an effect similar to an increase in inlet temperature. The antisurge control system therefore senses air inlet temperature and pressure and air discharge pressure to keep the compressor out of surge. The antisurge controls are integrated with the regular operating controls (see paragraphs 551-4.3.7.8.8 through 551-4.3.7.8.12), but take precedence over the operating controls.

551-4.3.7.8.8 Performance Curves of Centrifugal Compressors. The relationship of discharge pressure and compressor capacity at a constant operating speed is usually presented in a graphic form known as the compressor performance curve. Compressor discharge pressure is represented as the vertical coordinate (shown in the vertical direction on the graph paper), and capacity is shown as the horizontal coordinate. Each point of the performance curve represents the discharge pressure in the vertical column, and the corresponding capacity of the compressor in the horizontal column. The performance curve is accompanied by a horsepower curve which indicates the brake horsepower for any point of operation. If a compressor is operated at different speeds, there is a performance curve and horsepower curve for each speed. The centrifugal ships' service and O_2 N_2 producer plant compressors are operated at one speed and therefore only one set of curves is provided.

551-4.3.7.8.9 The performance and horsepower curves of a centrifugal compressor apply only to the compressor when operated at the rated air inlet conditions of temperature and pressure stated somewhere on the performance curve sheet or in the legend. When the rated inlet conditions are not stated and not known, the performance curves are of limited value. It also follows that when a compressor is operated at air inlet conditions different from the rated conditions, such as a much higher air inlet temperature, the performance of the compressor can be expected to deviate from the rated performance curve.

551-4.3.7.8.10 Accurate capacity checks are possible only under laboratory conditions. Onboard ship the rated performance curve is a sufficient indication of compressor capability. However, it is most important that the effect on compressor performance, when compressor air inlet conditions deviate from rated inlet conditions, be understood by the operators and users of the compressor.

551-4.3.7.8.11 Figure 551-4-20 shows a typical performance curve and illustrates how changes in inlet conditions affect compressor performance. The solid curve dropping off to the right indicates how the compressor capacity varies inversely with discharge pressure. It is the performance curve of the compressor when operated at the design (rated) inlet air conditions. The rising straight line, crossing the performance curve at A indicates that horsepower increases with increased compressor capacity (note that this is a horsepower versus capacity curve). The dotted lines suggest performance and horsepower curves resulting from a change in inlet air temperature. The straight broken line, marked surge line, defines the pumping limit or surge point for any performance curve (it is a line established by the aerodynamic design of the compressor and is confirmed by operating tests). The surge line divides the compressor's performance curve plot into a stable operating region to the right of the surge line and a nonoperating region to the left of the surge line. It is the region to the left of the surge line which the control system of the compressor seeks to avoid. It is of interest to note that the centrifugal compressor is inherently self-compensating; the capacity will go up or down as the air demand goes up or down as reflected by the discharge pressure.

551-4.3.7.8.12 Control of Performance. A compressor driven by a 350-horsepower motor cannot be cycled on and off but shall be allowed to operate continuously. Two methods of operation and control are employed to match compressor capacity with air demand. They are referred to as **base mode** and **intermittent mode** . Navy compressors operate in base mode only.

551-4.3.7.8.13 Base Mode. If a sustained air demand is anticipated that will be close to the capacity of the compressor with infrequent swings in requirements, the operator will select the base mode of operation. When in base mode, the control system maintains a fairly constant discharge pressure by modulating the opening and closing of a blowoff valve at the compressor discharge so that any excess compressed air is blown off to atmosphere, preferably overboard if the blowoff valve is located ahead (upstream) of the aftercooler.

551-4.3.7.8.14 The compressed air that is blown off in this manner represents a loss of energy. When the compressor is operated in base mode, it would be better to use the excess compressed air somewhere in the ship. It would certainly be false economy to be extra frugal in the use of compressed air, only to dispose of the savings through the overboard blowoff valve. It should be understood that in base mode operation all of the compressed air delivered at the discharge of the last stage should be dissipated at pressures below surge point pressure. It is the function of a properly operating control system to ensure that the compressed air is dissipated (used or blown off) otherwise the compressor would go into surge (see paragraphs 551-4.3.7.8.1 through 551-4.3.7.8.7).

551-4.3.7.9 Service Considerations. The general concerns that should be addressed when any complex rotating electrical machinery is to be operated apply most appropriately to the centrifugal air compressors. These precautions are discussed under reciprocating compressors in paragraph 551-4.2.22. Specific areas of concern relative to centrifugal compressors are described in the following paragraphs.

551-4.3.7.9.1 Personnel assigned to operating and maintenance tasks shall be fully trained and shall understand the performance characteristics and operating and control principles of centrifugal compressors.

551-4.3.7.9.2 Ensure that clean air free of water is provided to the seal air system and the electropneumatic control system. The compressor should not be operated unless this is assured.

551-4.3.7.9.3 Lubrication of the high-speed pinions particularly calls for absolute cleanliness of the lube oil supply and proper viscosity. Lube oil pressure alone is not an indication of adequate oil flow. The oil supply temperature should not be lower than 75° F. Operation of the compressor without oil filtration (filter bypassed or filter cartridge not in place) will result in early failure.

551-4.3.7.9.4 Regularly check that the intercooler demister/separator compartment is being drained continuously. There should be no condensate buildup. This will remove the risk of water ingestion by the impellers. Also, regularly check that there are no tube leaks in the intercoolers which would result in seawater ingestion by the impellers.

551-4.3.7.9.5 Regularly check that the intercoolers are providing sufficient cooling of the process air. Insufficient cooling will cause low air discharge pressure and may cause unstable compressor operation.

551-4.3.7.9.6 Regularly check that the line check valves and the power-operated discharge securing valves (if installed) are functioning properly. Reverse rotation of a secured compressor resulting from compressed air backflow will cause compressor damage.

551-4.3.7.9.7 When a compressor is not reaching the rated discharge pressure, suspect all of the following and verify the cause by eliminating first the causes that are most easily checked:

a. Ships' system is using more air than the compressor can supply.
b. Compressed air is being lost through the check valve of a secured compressor.
c. The temperature of the inlet air to the first stage is substantially higher than inlet design (rated) temperature.
d. The air inlet filter is clogged and causes the inlet pressure to be depressed.
e. The interstage coolers (intercoolers) are not performing the cooling function as required.
f. The inlet air control valve, the unloading control valves (at the third-stage discharge and at the moisture separator/chiller discharge), or the discharge securing valve are not functioning as required.
g. An impeller has been sheared from its pinion shaft (indicated by low discharge pressure and temperature from the specific stage).

551-4.3.7.9.8 The manufacturer's instruction manual and ships information book should be consulted for a more thorough treatment of each subject if required.

551-4.3.7.10 Deactivation and Preservation. When centrifugal compressors are secured indefinitely so that brief, weekly operation is not possible, it is necessary to preserve the compressor. The compressor, as an assembly, should be protected from the weather and from the ingress of dirt and dust that is prevalent in the environment. The lubricating system should be drained of used oil, flushed with clean oil, refilled with new oil, and operated for 15 minutes to fill oil passage and coat all areas normally covered with oil during operation. The bull and pinion gear assemblies should be coated with preservatives in a manner specified for reduction gears. All freshwater and seawater systems should be flushed with clean water and drained thoroughly with all vent and drain valves open. All water passages and cooler assemblies should be blown out with low-pressure clean dry air and ventilated with warm dry air for a sufficient length of time to ensure that the systems are dry and free of water. All control and monitoring instruments should be individually prepared for long term storage by cleaning, drying, and protective packing on site, or removed for separate storage. The storage warehouse or machinery space in which the compressor is retained should be maintained warm and dry to the maximum extent practicable. Safety measures necessary for the deenergizing and locked out disconnection of all electric power supplies shall be observed.

551-4.4 MISCELLANEOUS AIR COMPRESSOR APPLICATIONS

551-4.4.1 GENERAL. There are a number of air compressors onboard ship as indicated in Table 551-4-1 that supply compressed air for specialized services such as the PRAIRIE/MASKER (P/M) Air Emission System, LP deballasting, and diesel engine starting. The compressors for these services are briefly described in the following paragraphs. However, because of the specialized and limited application and the commonality of design with the ships' service compressors, refer to the manufacturer's manuals for a detailed description.

551-4.4.2 P/M COMPRESSORS. These compressors supply LP compressed air to special piping systems used exclusively for noise abatement. When in operation, the air usage for this requirement is continuous, at constant pressure, and with a constant rate of flow. Several modes of operation, however, may vary in air requirements. P/M air has been provided by bleed air from main gas turbines, oil-flooded rotary compressors, and motor-driven and steam turbine-driven centrifugal compressors. Centrifugal compressors are particularly well suited for P/M service because of the large-capacity, low-pressure requirement.

551-4.4.2.1 Motor-Driven Centrifugal P/M Compressors. Electric motor-driven centrifugal compressors have been installed on large ships as an alternative to steam turbine-driven compressors. A typical motor-driven P/M compressor is a two-stage design, without intercooling between stages, and with a capacity of 1,400 scfm when operating at the discharge pressure of 45 lb/in^2 g.

551-4.4.2.1.1 The compressor is driven by a 300-horsepower, 3,600 rpm motor through a speed increasing gear assembly at a final compressor operating speed of 43,380 rpm. When operated at the rated discharge pressure, the air reaches a discharge temperature of over 500° F. An aftercooler reduces the air temperature to 150° F. The compressor is oil lubricated with a conventional force-feed lubrication system, employing a 10 micron filter and a shaft-driven oil pump with a separate motor driven auxiliary oil pump for starting, stopping, and emergency backup.

551-4.4.2.1.2 An electropneumatic control system (similar in operating principle to that used on the LP ships' service centrifugal compressors) is provided. The control system automatically holds the discharge pressure to the desired adjustable setpoint pressure by modulation of the blowoff valve and suction valve located at the compressor discharge and inlet, respectively.

551-4.4.2.1.3 Unloaded operation of the compressor is not a P/M requirement. However, the antisurge control device temporarily unloads the compressor by opening the blowoff valve and partially closing the suction valve. A discharge pressure pulsation sensor switch initiates the antisurge unloading signal. A discussion of centrifugal compressor surge is given in paragraph 551-4.3.7.8.

551-4.4.2.1.4 The motor-driven P/M compressors are usually furnished in pairs, with one compressor serving as standby. The system alignment and control system are arranged to permit only one of the two compressors to operate at any time.

551-4.4.2.2 Steam Turbine-Driven P/M Compressors. The greatest number of P/M compressors in shipboard service is of the steam turbine-driven centrifugal type. The compressor has only one stage with a nominal capacity of 1,400 scfm at a discharge pressure of 25 lb/in^2 g when operating at a speed of 40,400 rpm.

551-4.4.2.2.1 The steam turbine is a noncondensing, single-stage impulse design operating at varying speed with a constant full-open steam admission valve which also serves as the overspeed trip valve. The turbine wheel and the compressor impeller are each mounted on opposite ends of a common horizontal shaft which is supported by two water tube combination journal/thrust bearings located between the turbine wheel and impeller. The turbine case and compressor housing are an integral casting, with a bolted-on endcover on the compressor side and a bolted-on steam chest with steam admission nozzles on the turbine side.

551-4.4.2.2.2 An air inlet silencer is bolted directly to the compressor diffuser plate. An access panel on the silencer, opposite to the impeller inlet nozzle, permits manual spin-rotation of the compressor rotor as a means of determining the condition and performance of the water-lubricated bearings (see paragraph 551-4.4.2.4). The compressor is mounted atop the lube water reservoir. An electric motor-driven lube water pump and a lube water cooler are mounted on the side of the reservoir.

551-4.4.2.3 Special Features of the Turbine-Driven P/M Compressor. Special design features of the compressor are the high operating speed and the use of fresh water as the bearing lubricant. The compressor was originally designed with these features to achieve a compact design needed for commercial superchargers applications. The design was adopted for Navy service because it was particularly suitable for back fitting on space-critical ships, as was the case in the first P/M installations. The use of water as a bearing lubricant ensures constant viscosity at high compressor rpm, provided the lube water temperature remains below 212° F. Water lubrication also eliminates the problems of the lube oil contamination with condensate and condensate contamination with lube oil problems that are commonly experienced with close-coupled integral steam-turbine driven machinery.

551-4.4.2.4 Lubricating System of Turbine-Driven P/M Compressors. The compressor rotor is supported on two water-lubricated, combined thrust and journal bearings incorporating a series of wedge-type depressions which are supplied with fresh water through axial and radial holes at a bearing inlet pressure of 65 to 85 lb/in^2 g. Water flow rate to each bearing is about 8 gpm with a bearing supply and bearing discharge water temperature of 150° F and 160° F, respectively.

551-4.4.2.4.1 When the rotor is at standstill with no lube water flowing, the rotor is supported in the bearings with metal-to-metal contact. With the lube water pump in operation, the rotor floats in the bearings by hydrodynamic forces and will spin freely by hand without metal-to-metal contact. When the compressor is driven by the turbine, the wedged areas of the bearings develop hydrodynamic forces, both radially and axially, to give the bearing the necessary stiffness for continuous nonrubbing operation. Interacting controls prevent steam admission to the turbine without prior adequate lube waterflow to the bearings.

551-4.4.2.4.2 The lube water system incorporates the necessary conventional controls and monitor, such as low-pressure and high-temperature lube water alarms and automatic compressor shutdown. A salinity monitor and alarm guard against seawater leaks in the water cooler.

551-4.4.2.4.3 Extra-fine water filtration is provided in the form of full-flow, 10 micron filters for both the forced-feed lubrication system and for filtration of makeup water. The filter cartridge is of the throw-away noncleanable type. The filter does not and should not incorporate an internal or external bypass. Where it is possible to reassemble the filter without a filter cartridge in place, it is advisable to institute an alteration to render this impossible or make the absence of a filter cartridge obviously detectable.

551-4.4.2.4.4 All water lubricated compressors are equipped with an air-pressurized emergency lube water tank, independent of the regular lube water reservoir. The pressurized emergency tank floats on the bearing water supply line, so that when the water supply to the bearing suddenly fails due to pump or circulating system failure, the air pressure in the emergency water tank maintains pressurized waterflow to the bearing for a sufficient length of time to permit the compressor to coast to a halt without bearing damage. Normally, the emergency tank totally ejects its water content during pump shutdown. On restarting of the pump, the emergency tank is automatically refilled with water to the level at which the trapped air in the tank (equal to the volume of the tank) is compressed to the pressure of the water pump discharge.

551-4.4.2.4.5 The inclusion of air in the pump discharge at initial startup and the gradual takeup of air in the water during prolonged continuous operation may alter the water level in the emergency tank. The water level is restored by means of a Schrader-type air valve which allows air to be added or be bled off. It is therefore important that the water level sight glass of the emergency water tank be monitored regularly, because only a water level at the specified level marks will ensure sufficient waterflow at adequate pressure when an emergency requirement occurs.

551-4.4.2.5 P/M Compressor Performance. Unlike the LP ships' service centrifugal compressors which operate at a constant speed, the turbine-driven P/M compressors operate at constant power. This means that the compressor will seek exactly the rotative speed at which the compression work, as determined by the discharge pressure (air system back pressure), equals the power input. Since it is the system back pressure against which the compressor operates that determines the compressor speed, influencing the discharge pressure directly effects the speed of the compressor.

551-4.4.2.5.1 At a compressor discharge pressure of 25 lb/in^2 g with steam admission of 310° lb/h, the compressor will operate at a speed of 40,400 rpm. As discharge air pressure goes up (that is, as flow through the compressor is throttled), the speed of the compressor increases. Therefore, for protection from overspeed, a pressure switch, sensing increasing compressor discharge pressure and set at 31.5 lb/in 2 g equivalent to a speed of 42,300 rpm, actuates the overspeed trip to shut down the compressor. The diagonal line, intersecting the constant speed and constant steam rate curves is the compressor surge line (see paragraph 551-4.3.7.8). The overspeed trip prevents the compressor from reaching the surge point.

551-4.4.3 DEBALLASTING COMPRESSORS. Compressors used for LP deballasting are positive displacement rotary twin-screw compressors, driven directly at constant speed by single-speed and sometimes two-speed electric motors. The twin screws, sometimes called spiraxial rotors, mesh with each other at a very close clearance but without contact. Timing gears are provided to prevent contact between the rotors. The rotors operate dry without lubricating or sealing fluid in the compressing area. The compressed air is therefore oil-free; no oil or water separator is required. A forced-feed lube oil system lubricates the outboard bearings and the timing gears. Each compressor is equipped with an air inlet silencer and a discharge silencer.

551-4.4.3.1 Roots Blowers. The compressors are usually referred to as Roots Blowers, a product of Roots Division of Dresser Industries. Much smaller and lower pressure Roots Blowers are used for other applications onboard ship such as sewage agitation, but the deballasting application is the most notable. On submarines, the Roots Blower proved to be the most reliable and efficient method for regular LP blow surface deballasting of the main ballast tanks and as a means of machinery space ventilation.

551-4.4.3.2 Power Requirements. As is the case with all positive displacement compressors, the brake horsepower to drive the rotary deballasting compressor varies directly with discharge pressure. This means the higher the deballasting pressure, the higher the brake horsepower will be. The rating of the electric motor should then match the brake horsepower required to drive the compressor at its maximum operating pressure. This is true when the compressor is required to operate for long periods at the maximum discharge pressure.

551-4.4.3.2.1 However, in some deballasting applications, principally on submarines, the deballasting evolution is initiated at a low-pressure; that is, 20 percent of maximum pressure. The brake horsepower to drive the compressor at this low-pressure will be less than half of the required power at the maximum deballasting pressure. As deballasting proceeds, the discharge pressure rises, as does the brake horsepower. The compressor cam be shut down the moment the maximum pressure is reached. It is therefore possible to provide a motor having a substantially lower rating than the full power rating at maximum pressure, as long as the total deballasting evolution is of short duration (20 to 40 minutes) and the temperature of the motor windings does not exceed the permissible temperature rise during the brief period of overloaded operation.

551-4.4.3.2.2 Deballasting compressors equipped with low horsepower motors should be equipped with a suitable control feature for reliable automatic compressor shutdown on completion of the deballasting operation. Additionally, it is advisable that the electric motor be fitted with an overtemperature shutdown switch.

551-4.4.3.3 Performance and Operation. The rotary deballasting compressors in shipboard service range in capacity from 1,100 to 2,200 scfm and operate at discharge pressures not exceeding 24lb/in^2 g. The compressors may be operated in parallel, as with two or more discharging to a common deballasting system. In such a multiple arrangement, reliable operating check valves shall be installed in the discharge line of compressors to prevent back flow and reverse wind-milling of a secured compressor.

551-4.4.3.3.1 Operation of the compressor at a discharge pressure higher than the design operating pressure causes unacceptable high temperatures of the rotors and housing and will result in rapid compressor failure. Excessive discharge pressure may also cause distortion of the rotors and rubbing contact between rotors and housing. The relief valve in the compressor discharge shall therefore be of adequate capacity, it shall be properly set, and it shall be maintained functional.

551-4.4.3.3.2 The compressor should not be started except with positive assurance that the discharge valves or special blowoff valve (if provided) are open, to permit the compressor to come up to speed with free delivery of the discharge air to atmosphere or to an open large volume air system. An automatic overpressure shutdown switch, to protect against excessive discharge pressure, is usually provided on each compressor. High air temperature shutdown switches are not provided because the compressor shutdown would come too late and provide no protection. Special attention is required in the case of deballast compressors to ensure that foreign material such as grit, sand, and rust particles do not enter, and that water does not run into the compressor from weather openings communicating with relief valves and blowoff valves from the deballast system itself and from water spray near the compressor air intake.

551-4.4.4 DIESEL ENGINE STARTING COMPRESSORS. Small capacity reciprocating compressors of the oil-lubricated type have been provided on most diesel engine powered ships for engine starting. Two standard sizes are in service: 50 scfm at 600 lb/in^2 g discharge pressure, and 10 scfm at 600 lb/in^2 g pressure. They are suitable for continuous service. However, the duty cycle, as engine starting compressors for which they were designed and selected, does not compare with the severe day-to-day demands on LP ships' service air compressors.

551-4.4.4.1 The use of diesel engine starting compressors for ships' service air is not advisable except in case of emergency or where the air requirements are infrequent and minimal. The design and operation of these compressors is similar to the high-pressure and ships' service air reciprocating compressors described in paragraphs 551-4.2 and 551-4.3, respectively. The manufacturer's manuals should be consulted for detail design features and maintenance.

551-4.5 AIR DEHYDRATORS

551-4.5.1 MIL-SPEC AIR DEHYDRATORS. LP air dehydrators are furnished according to two different Military Specifications. MIL-D-23523 defines Type I (refrigerant) and Type II (desiccant) dehydrators, and MIL-D-24693 describes requirements for Condenser-Filter (chill water) type dehydrators. HP (3,000 lb/in^2 /5,000 lb/in^2) air dehydrators furnished according to MIL-D-17847 are of the dessicant type only. For information concerning specific design features and maintenance of a dehydrator, refer to the applicable manufacturer's technical manual.

551-4.5.2 TYPE I LP AIR DEHYDRATOR. The following paragraphs provide guidance in the operational maintenance of type I LP air dehydrators.

551-4.5.2.1 Description. The dehydrator is a self-contained, fully automatic, regenerative compression, refrigerant type unit designed to remove vaporous water, oil, and solid contaminants from LP compressed air systems aboard ship. The dehydrator is designed for continuous, automatic operation. It requires a source of compressed air at a pressure between 80 and 150 lb/in^2 . Moisture removal is achieved by cooling the airstream with low temperature refrigerant. The condensed moisture is mechanically separated from the airstream and automatically dumped by a trap-dump valve. Oil aerosol is removed by a combination of condensation and mechanical coalescence. Solid contaminants are removed by mechanical filtration. Dehydrator performance is shown in Table 551-4-3.

Table 551-4-3 TYPE I DEHYDRATOR PERFORMANCE

Airflow-Influent	
Maximum temperature Pressure Maximum moisture content	125° F 80 to 150 lb/in^2 gauge 0.015 lb H_2 O/lb air
Airflow-Effluent	
Maximum temperature Pressure Maximum moisture content	110° F 75 to 150 lb/in^2 gauge 0.00085 lb H_2 O/lb air (40° F dewpoint at 80 lb/in^2 gauge)

551-4.5.2.2 Operation. The dehydrator (see Figure 551-4-23) works by chilling the compressed airstream, which causes water vapor to condense out of the stream as liquid. Separation and dump mechanisms are provided to drain the condensate out of the airstream and to remove it from the system. Moisture-laden air saturated at the ships' service LP air compressors discharge temperature enters the dehydrator and immediately passes through a separator.

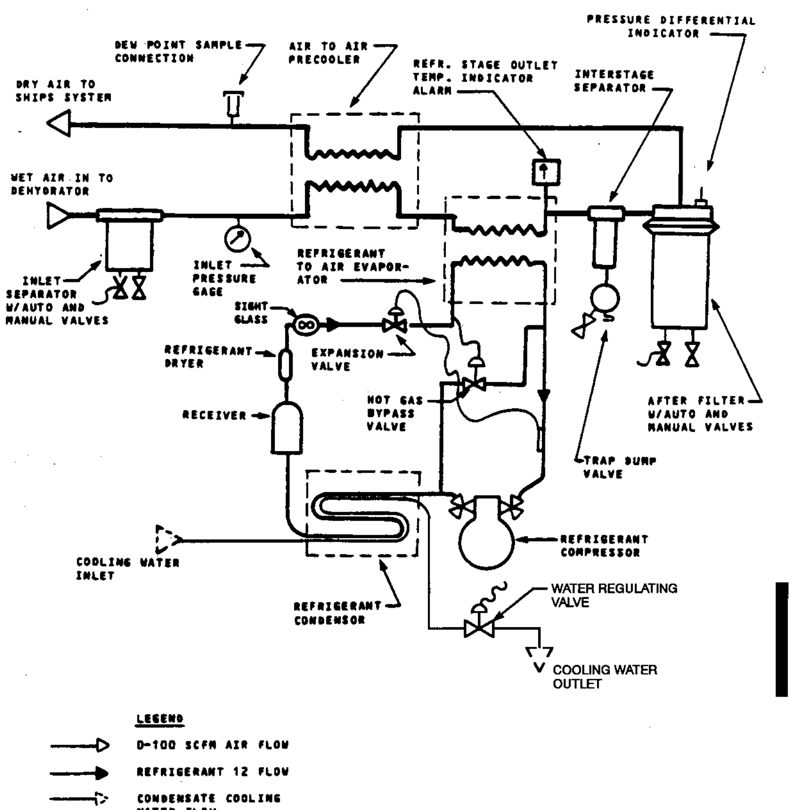


Figure 551-4-23 (Type I) LP Dehydrator - Schematic Flow Diagram

551-4.5.2.2.1 This separator removes liquid water which may be carried out of the compressor aftercooler (see Figure 551-4-24). The warm, wet air then enters the heat exchanger. The first half of the exchanger is an air-to-air precooler. Here, the hot air runs counter to the cold, dry outlet air. After leaving the precooler, the partially cooled inlet air enters the refrigerant evaporator. Here, low temperature Refrigerant 12 removes more heat from the airstream, reducing its temperature to the desired 34° F to 40° F and condensing more water vapor from the air.

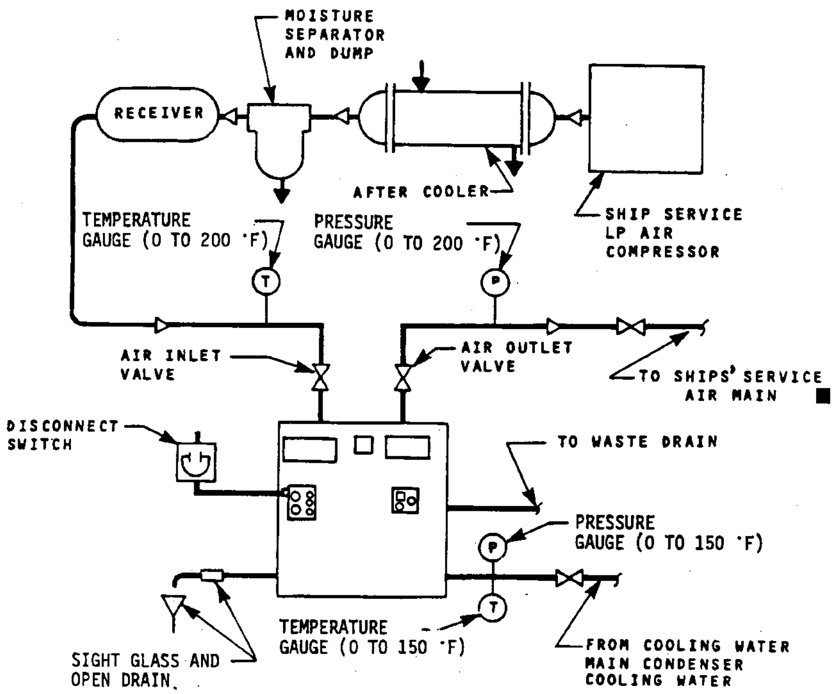


Figure 551-4-24 Typical Installation Schematic - (Type I) LP Dehydrator

551-4.5.2.2.2 The cold air leaves the heat exchanger and passes over the sensing bulb of the temperature indicator/alarm, which shows the actual temperature reached by the air. Next, the cold air flows through another separator, similar in construction to the inlet separator. Instead of using the float switch solenoid valve to dump the condensate, the interstage separator empties into a large trap dump valve. The trap dump valve is a float actuated, pneumatically operated device, and has a magnetic latch to ensure good blowdown. It also has a manual drain valve.

551-4.5.2.2.3 From the interstage separator, the cold air passes through the afterfilter. The afterfilter ensures that the last traces of moisture are removed, along with any solid particles and oil compressor receives only vapor. Liquid at the compressor suction can damage the compressor. The expansion valve throttles the warm liquid to a lower pressure, causing it to lose temperature and start to boil. The hot gas bypass sensing port is immediately downstream from the expansion valve outlet.

551-4.5.2.2.4 The low temperature refrigerant flows through the evaporator, where it removes heat from the air and boils into a vapor (evaporates). The cool vapor leaves the evaporator, passes the hot gas injection port and the expansion valve sensing bulb, and enters the compressor to be recirculated through a suction service valve. The suction line includes a turbulator to ensure good mixing between cool and hot gas streams.

551-4.5.2.2.5 If the cooling load drops, the expansion valve automatically reduces the refrigerant flow rate. This reduces the pressure at which the refrigerant is boiling, and with it the temperature. With no other controls, the evaporator would freeze up. To prevent freeze-up, the hot gas bypass begins to open when the evaporator pressure falls and injects hot gas into the suction line. This raises evaporator pressure and temperature and prevents freeze-up. Water from the seawater cooling main enters the dehydrator sediment strainer which removes solid matter. The water then passes through a regulating valve. This drops from the airstream. The filter includes a float switch, solenoid valve, and manual valve like those in the inlet separator. The cold, clean, dry air returns to the air-to-air heat exchanger and passes through the other side of the precooler. Finally, the warm, dry air leaves the dehydrator.

551-4.5.2.2.6 The refrigerant compressor compresses Refrigerant 12 vapor and discharges it through a discharge service valve. The discharge (head) pressure is controlled by the condenser water control valve. From the service valve, the hot refrigerant gas goes to the inlet of the hot gas bypass valve and to the condenser. There is a purge valve on the condenser inlet which allows the mechanic to bleed the system.

551-4.5.2.2.7 In the condenser, heat is removed by the circulating cooling water, condensing the hot gas into a warm liquid. From the condenser, the liquid passes the water regulating valve sensing port and then into the receiver. The receiver provides storage volume and a pressure ballast. From the receiver, the liquid flows through a dryer, which removes trace moisture from the refrigerant. From the dryer, the liquid enters the expansion valve. The expansion valve is thermostatically controlled to ensure that the refrigerant flows at a rate which will allow from 6° F to 8° F superheat at the compressor suction. (This ensures the compressor receives only vapor. Liquid at the compressor suction can damage the compressor.) The expansion valve throttles the warm liquid to a lower pressure, causing it to lose temperature and start to boil. The hot gas bypass sensing port is immediately downstream from the expansion valve outlet.

551-4.5.2.2.8 The low temperature refrigerant flows through the evaporator, where it removes heat from the air and boils into a vapor (evaporates). The cool vapor leaves the evaporator, passes the hot gas injection port and the expansion valve sensing bulb, and enters the compressor to be recirculated through a suction service valve. The suction line includes a turbulator to ensure good mixing between cool and hot gas streams.

551-4.5.2.2.9 If the cooling load drops, the expansion valve automatically reduces the refrigerant flow rate. This reduces the pressure at which the refrigerant is boiling, and with it the temperature. With no other controls, the evaporator would freeze up. To prevent freeze-up, the hot gas bypass begins to open when the evaporator pressure falls and injects hot gas into the suction line. This raises evaporator pressure and temperature and prevents freeze-up. Water from the seawater cooling main enters the dehydrator sediment strainer which removes solid matter. The water then passes through a regulating valve. This valve controls the water flow rate to maintain a fairly constant refrigerant discharge (head) pressure. The water then flows through the condenser, which is a multipass, counterflow heat exchanger.

551-4.5.2.3 Operating Procedure. Use the following procedure to operate the dehydrator:

1. Turn on and check that the refrigeration compressor fan is enclosed by its guard and is free from any obstructions.
2. Line up cooling water to the refrigerator condenser. Check proper pressure (35 lb/in^2 g, minimum; 100 lb/in^2 g, maximum). Adjust inlet cooling water regulating valve as necessary.
3. Check that the air outlet valve is closed.
4. Open the air inlet valve. Check that inlet air pressure is within design limits (80 to 150 lb/in^2 g). The unit is now in STANDBY.

5. Turn the Power-On switch ON. The refrigeration compressor and its cooling fan will start running. The unit is now IN OPERATION.
6. Check to ensure that the Temperature Indicator/Alarm shows that the unit is cooling.

NOTE

This dehydrator is fully automatic and is designed for continuous duty. However, this does not mean that it should be operated with no attention whatsoever. GOOD ENGINEERING PRACTICE DEMANDS THAT AN OPERATING LOG BE MAINTAINED. It is strongly recommended that operating data be logged on an hourly basis. If accurate logs are maintained, they can be of great assistance in determining the cause of a malfunction, and can even predict a malfunction before the dehydrator begins to deliver wet air.

7. When the refrigerated stage temperature reaches 50° F, open the air outlet valve.

551-4.5.2.4 Monitoring. The following controls and indicators are provided to monitor dehydrator performance:

a. Power-On light is lit when Power-On switch is ON.
b. Refrigeration Temperature Alarm light is lit when the refrigerated air temperature rises above 50° F.
c. Lamp Test switch energizes the Refrigeration Temperature Alarm light when the switch is depressed.
d. The temperature alarm consists of the light and a buzzer.
e. The temperature alarm is also provided with an external output.
f. Elapsed Time indicator indicates cumulative operating time.
g. Temperature indicator/alarm indicates the temperature of the air leaving the refrigerator evaporator, and energizes an alarm system if the temperature goes outside design limits. In normal operation, the temperature should run between 34° F and 40° F.
h. Inlet pressure gauge indicates the pressure of the air entering the dehydrator. In normal operation it should run between 80 and 150 lb/in^2 g.
i. Refrigerant (R-12) compressor suction pressure is 28-32 psi and discharge pressure is 125-135 psi.

551-4.5.2.5 Securing. Use the following procedure to secure the dehydrator:

1. Close the air outlet valve.
2. Turn the Power-On switch OFF. The Power-On light will go out and the refrigeration compressor and its fan will stop. The unit is now in STANDBY.
3. Close the air inlet valve.
4. Secure the refrigeration condenser cooling water. The unit is now OFF.

551-4.5.3 TYPE II LP AIR DEHYDRATOR. The following paragraphs provide guidance in the operational maintenance of type II LP air dehydrators.

551-4.5.3.1 Description. The dehydrator is a self-contained unit designed to remove vaporous water and oil, and solid contaminants from LP air systems aboard ship. The dehydrator is designed for continuous, automatic operation. It requires a source of compressed air at a pressure between 80 and 150 lb/in^2 g. It is capable of delivering air at a dewpoint of -40° F at 80 lb/in^2 g (0.000015 pounds of water per pound of dry air).

551-4.5.3.1.1 To allow continuous operation, the dehydrator is provided with two desiccant chambers in parallel. While one chamber is dehydrating the airstream, the other is being reactivated. The most common type II dehydrator found in the fleet has a capacity of 30 scfm. Dehydrator performance is shown in Table 551-4-4.

Table 551-4-4 TYPE II DEHYDRATOR PERFORMANCE

Airflow-Influent	
Maximum temperature Pressure Maximum moisture content	105° F 80 to 150 lb/in^2 gauge 0.008 lb H_2 O/lb air
Airflow-Effluent	
Maximum temperature Pressure Maximum moisture content	160° F 67 to 150 lb/in^2 gauge 0.000015 lb H_2 O/lb air (-40° F dewpoint at 80 lb/in^2 gauge)

551-4.5.3.2 Operation. Moist, low-pressure air is delivered to the dehydrator (see Figure 551-4-25) through an inlet shutoff valve. The air enters the inlet filter assembly. Here, a combination of centrifugal force and mechanical filtration removes particulate contaminants, oil aerosol, and condensed moisture. Accumulated water is drained from the assembly by an automatic drain valve. After being filtered, the air travels through a solenoid valve to the desiccant chamber, where it is dried. The air then passes through the desiccant chamber where the desiccant absorbs moisture from the air, yielding air with the required low moisture content.

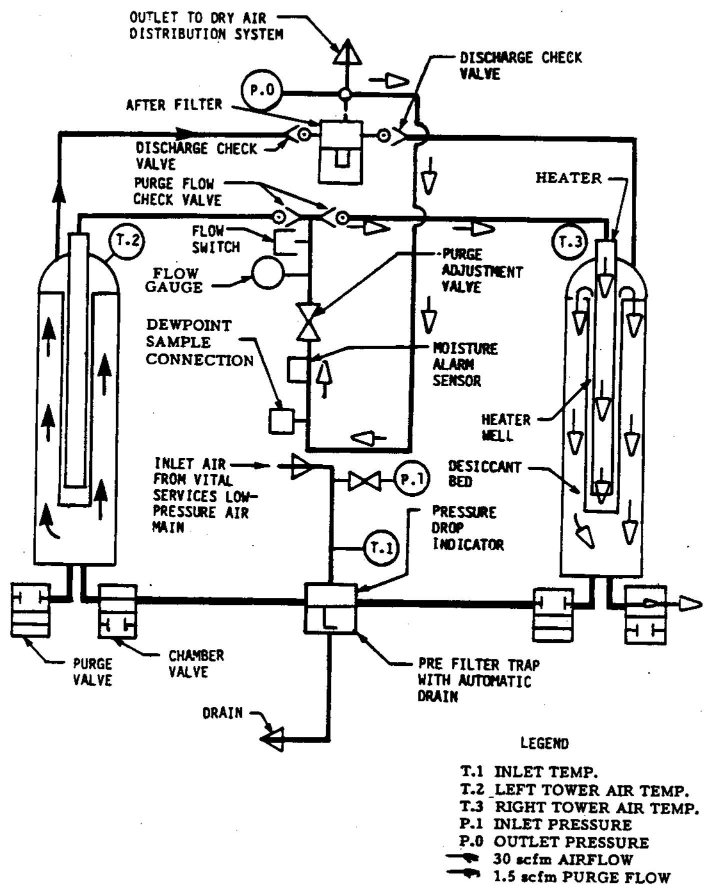


Figure 551-4-25 (Type II) LP Dehydrator - Schematic Flow Diagram

551-4.5.3.2.1 After exiting the chamber, the dry air passes through a check valve and then through the outlet filter. The function of this filter is to ensure that no traces of solid contaminant pass into the ships' dry air system or into the purge air system. After the outlet filter, the clean, dry air passes over the dewpoint alarm sensor, which measures the moisture content of the air.

551-4.5.3.2.2 The airflow is then split into two streams: effluent air into the ships' dry air system, and purge air into the dehydrators purge air system. Effluent air leaves the dehydrator through an outlet shutoff valve. Purge air is taken back through a control valve and a variable area flowmeter. The valve allows the operator to adjust the purge flow rate, and the flowmeter indicates the flow. The reed switch monitors the flow rate to cut out the chamber heaters in the event of insufficient purge flow.

551-4.5.3.2.3 The metered purge air leaves by way of a check valve. The purge air then flows through the desiccant bed being reactivated. During the first portion of the reactivation cycle, the air carries heat into the desiccant, causing it to desorb its captured moisture. Then, the purge air cools the desiccant to operating temperature for the next drying period. During the heating period, a temperature switch monitors reactivation temperature and secures the heater when adequate temperature has been attained. From the chamber, purge air vents to atmosphere by way of the solenoid valve and muffler.

551-4.5.3.2.4 In the later design, metered purge air is taken from the outlet manifold back to the chamber through an external line. The air flows up through a tube in the center of the heater and then back down through the space between the heater and the heater shield. Then it flows over the temperature controller sensor bulb. A separate controller is provided for each chamber to limit reactivation temperature and to indicate the temperature. Leaving the chamber, purge air is discharged from the dehydrator.

551-4.5.3.3 Operating Procedure (refer to Figure 551-4-26). Use the following procedure to operate the dehydrator:

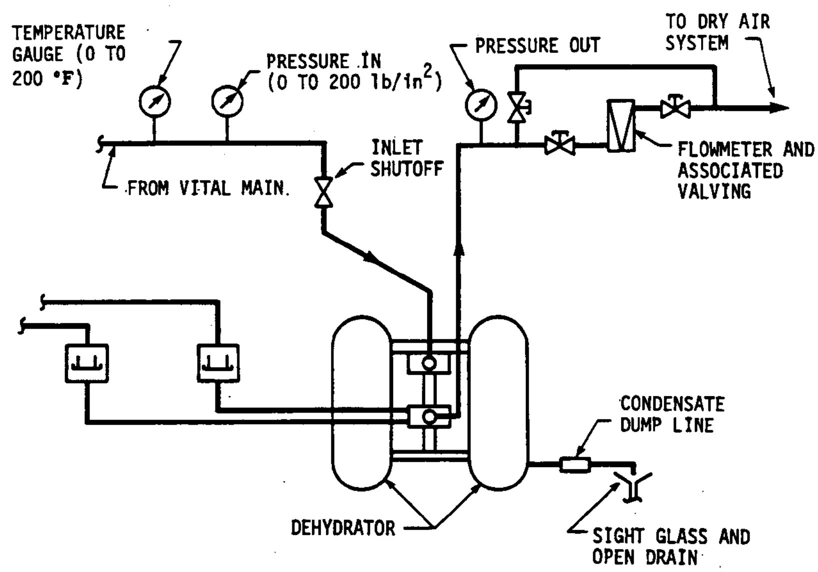


Figure 551-4-26 Typical Installation Schematic - (Type II) LP Dehydrator

1. Start up and commence the operating log.
2. Check to see that chamber temperature controllers are set according to the equipment technical manual.
3. Open the air inlet valve. Check to ensure that inlet air pressure is between 80 and 150 lb/in^2 g. If inlet pressure is below 80 lb/in^2 g or over 150 lb/in^2 g, report to the Engineering Watch Officer and advise that the dry air supply is in danger unless the situation is corrected.
4. Provide power to the unit.
5. When conditions have stabilized after about 1 minute, check to ensure that purge flow is as required by operating instruction plate.
6. Outlet valve closed until humidity light goes out, then test air quality with frost point indicator.
7. Open the air outlet valve.

NOTE

This dehydrator is fully automatic and is designed for continuous duty. However, this does not mean that it should be operated with no attention whatsoever. GOOD ENGINEERING PRACTICE DEMANDS THAT AN OPERATING LOG BE MAINTAINED. Because of the cycle times involved, it is strongly recommended that operating data be logged on an hourly basis. If accurate logs are maintained, they can be of great assistance in determining the cause of a malfunction, and can even predict a malfunction before the dehydrator begins to deliver wet air.

NOTE

In order to keep operating time even, it is recommended that units be rotated every 200 operating hours or weekly. This rotation will also tend to keep the standby unit dry.

551-4.5.3.4 Monitoring. The following indicators are provided to monitor dehydrator performance:

a. The indicator lights **inlet pressure, outlet pressure, purge flow** , and chamber temperature are provided. Together with the reactivation temperature indicators, these lights give the operator a complete picture of the dehydrator's status.

b. Dewpoint indicator system closes an alarm circuit when the moisture content of the air leaving the dehydrator exceeds preselected level.

551-4.5.3.5 Securing. Use the following procedure to secure the dehydrator:

1. Close the air outlet valve. The dehydrator may be operated in this **dead-ended** condition for up to 24 hours.

2. If possible, shut down only when both chambers are cool to prevent possible overheating of any components. The dehydrator may be secured at any time, however, with no short-term damage as long as purge flow is maintained until the towers are cooled.

3. Close the air outlet valve.

4. Secure electrical power.

5. Stop the operating log.

551-4.5.4 TYPE III LP AIR DEHYDRATOR. The following paragraphs provide guidance in the operational maintenance of type III LP air dehydrators. Type III dehydrators combine the dehydration methods of the Type I and II dehydrators into one self-contained unit. Type III dehydrators are no longer installed on surface ships, but are still used on several submarine classes. Type III dehydrators are no longer used in any new ship designs.

551-4.5.4.1 Description. The dehydrator is a self-contained, fully automatic unit designed to remove vaporous water and oil, and solid contaminants from LP compressed air systems aboard ship. The dehydrator is designed for continuous, automatic operation. It requires a source of compressed air at a pressure between 80 and 150 lb/in^2 g.

551-4.5.4.1.1 Moisture removal is achieved by cooling the incoming wet air in the refrigeration stage. This condensed moisture is mechanically separated from the airstream and automatically dumped by a trap dump valve. The air is then further dried by passing it through a chamber of desiccant. While one chamber is dehydrating the airstream, the other is being reactivated. Oil aerosol is removed by a combination of condensation and mechanical filtration. Solid contaminants are removed by mechanical filtration. The dehydrator performance is shown in Table 551-4-5 and Table 551-4-6.

Table 551-4-5 TYPE III DEHYDRATOR PERFORMANCE STAGE

Airflow-Influent	
Maximum temperature Pressure Maximum moisture content	125° F 80 to 150 lb/in^2 gauge 0.015 lb H_2 O/lb air
Airflow-Effluent	
Maximum temperature Pressure Maximum moisture content	105° F 75 to 150 lb/in^2 gauge 0.0022 lb H_2 O/lb air (65° F dewpoint at 80 lb/in^2 gauge)

Table 551-4-6 TYPE III DEHYDRATOR PERFORMANCE

Airflow-Influent	
Maximum temperature Pressure Maximum moisture content	105° F 75 to 150 lb/in^2 gauge 0.004 lb H_2 O/lb air (85° F dewpoint at 80 lb/in^2 gauge)
Airflow-Effluent	
Maximum temperature Pressure Maximum moisture content	105° F 62 to 150 lb/in^2 gauge 0.000015 lb H_2 O/lb air (-40° F dewpoint at 80 lb/in^2 gauge)

551-4.5.4.2 Operation. The dehydrator (see Figure 551-4-27) works by a combination of refrigeration and adsorption. Hot, wet air from the ships' service LP air system enters the dehydrator through a Sil-Braze union connection. The air immediately encounters an automatic inlet solenoid valve. From the valve, the air passes through an inlet separator. When the collected water rises to a certain level, a float closes a switch and opens a solenoid valve to dump the water. There is also a manual valve which also drains the separator.

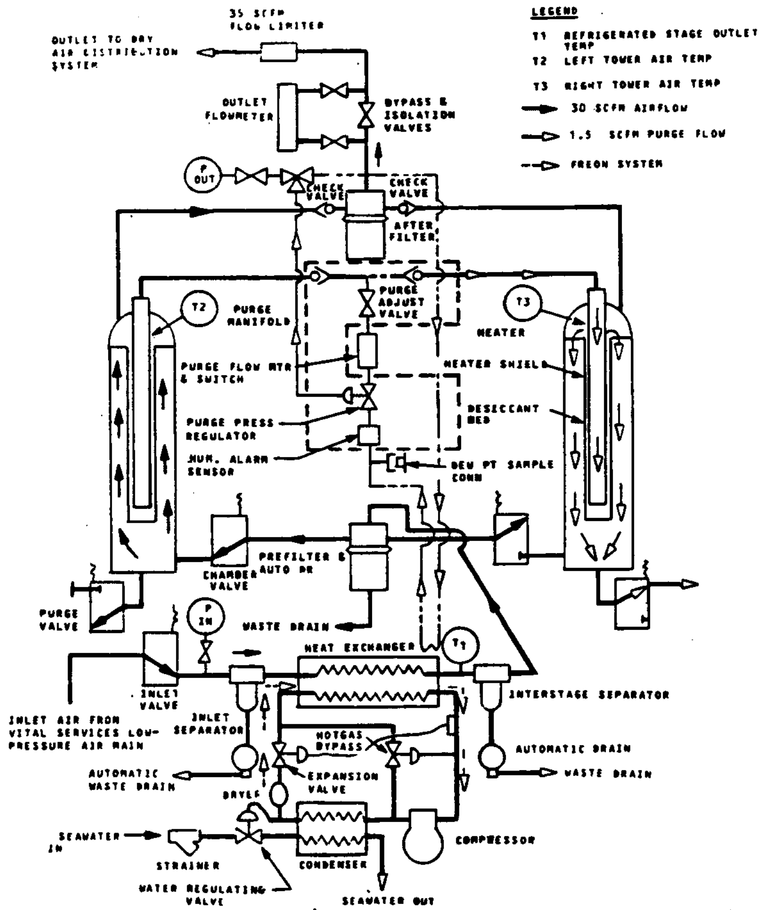


Figure 551-4-27 (Type III) LP Dehydrator - Schematic Flow Diagram

551-4.5.4.2.1 The hot, wet air then enters the heat exchanger. Low-temperature Refrigerant 12 removes heat from the airstream, reducing its temperature to the desired 34° F to 60° F and condensing water vapor from the air. The cold air leaves the heat exchanger and passes over the sensing bulb of the temperature indicator/alarm. Next, the cold air flows through the interstage separator. Instead of using the level switch and solenoid valve to dump the condensate, the interstage separator empties into a large trap dump valve. From the interstage separator, the cold air passes through the prefilter.

551-4.5.4.2.2 The cold, partially-dried air flows through a chamber inlet valve into the desiccant chamber. In this chamber, the desiccant adsorbs more moisture from the air, yielding the required low moisture content. The air exits the chamber through a check valve and enters the afterfilter. After leaving the afterfilter, the clean, dry air is split into two streams: effluent air into the ships' dry air system, and purge air through the purge air system.

551-4.5.4.2.3 In the outlet air piping, there is a pressure tap to the outlet pressure gauge, the air passes through the outlet flowmeter, which shows airflow rate into the ships' system. The flowmeter is supplied with isolation and bypass valves. Finally, the effluent air passes through a flow limiter, a device designed to restrict airflow.

551-4.5.4.2.4 The purge airstream is taken back through a separate pass in the air-to-Freon heat exchanger, where its temperature is reduced to about 50° F. The purpose of this is to provide a stable temperature of the air being monitored by the humidity alarm sensor, which is a temperature-sensitive device. From the heat exchanger, the purge air goes into a manifold assembly. On this manifold, there is an outlet to a connector on the instrument panel to allow the use of a low-pressure frost point indicator. (This frost point indicator is an item of special test equipment, not supplied with the dehydrator.)

551-4.5.4.2.5 After its pressure is reduced, the purge air flows through a flowmeter which indicates purge flow rate in scfm. The metered air flows back into the manifold and out through a check valve to the chamber on reactivation service. In the chamber, the air flows over the heater and then strikes the temperature controller sensor. A controller is provided for each chamber to limit reactivation temperature. The purge air flows down through the desiccant, at first heating it to cause it to desorb its captured moisture, and then cooling it to operating temperature for its subsequent dehydration service. Finally, the purge air flows to atmosphere through the purge valve.

551-4.5.4.2.6 The condensate dumps from inlet separator, trap dump valve, and prefilter manifold together and drain through a Sil-Braze union. The refrigerator compressor compresses Refrigerant 12 vapor and discharges it through a discharge service valve. From the service valve, the hot refrigerant gas goes to the inlet of the hot gas bypass valve and to the condenser. From the condenser, the liquid passes the water regulating valve sensing port and then into the receiver. The receiver provides storage volume and a pressure ballast. From the receiver, the liquid flows through a dryer, which removes trace moisture from the refrigerant. From the dryer, the liquid enters the expansion valve. The expansion valve throttles the warm liquid to a lower pressure, causing it to lose temperature and start to boil. The hot gas bypass injection port is immediately downstream from the expansion valve outlet.

551-4.5.4.2.7 The low temperature refrigerant flows through the evaporator, where it removes heat from the air and boils into a vapor (evaporates). The cool vapor leaves the evaporator, passes the hot gas sensing port and the expansion valve sensing bulb, and enters the compressor to be recirculated. Heat is removed from the hot refrigerant gas to condense it into a liquid. The heat is removed by a seawater heat exchanger.

551-4.5.4.2.8 Water from the cooling main enters the dehydrator through a Sil-Braze union. It passes through a sediment strainer which removes solid matter. The clean water then passes through a regulating valve. This valve controls the water flow rate to maintain a fairly constant refrigerant discharge (head) pressure. The water then flows through the condenser, which is a multipass counterflow heat exchanger.

551-4.5.4.3 Operating Procedure (refer to Figure 551-4-28). Use the following procedure to operate the dehydrator:

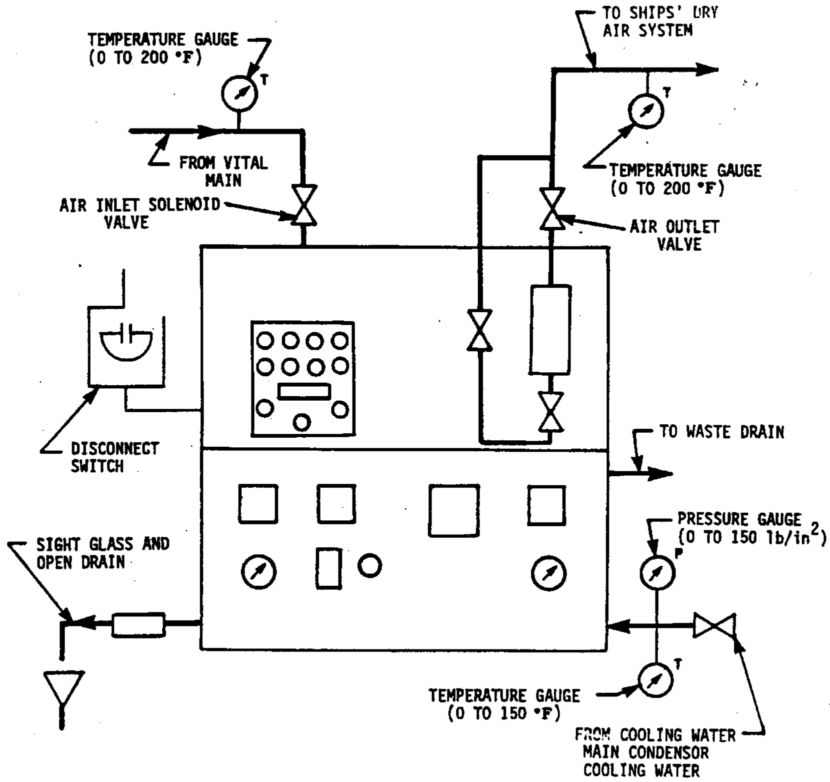


Figure 551-4-28 Typical Installation Schematic - (Type III) LP Dehydrator

1. Turn on and check to see if the refrigeration compressor fan is enclosed by its guard and is free from any obstructions.

2. Line up cooling water to the refrigerator condenser. Check adequate pressure (35 lb/in^2 g, minimum; 100 lb/in^2 g, maximum). Adjust the inlet cooling water regulating valve as necessary.

3. Set controllers for 400° F.

4. Check that the outlet flowmeter outlet isolation and bypass valves are closed. The unit is now in STANDBY.

5. Turn the Power-On switch ON. The Power-On light and one Chamber Reactivating light will light. The refrigeration compressor and its cooling fan will start running. The air inlet solenoid valve will open, admitting air to the dehydrator. Check that inlet air pressure is within design limits (80 to 125 lb/in^2 g). The unit is now IN OPERATION.

6. Check to ensure that the Temperature Indicator/Alarm shows that the unit is cooling.

7. Check that the Humidity Alarm is OFF, showing that outlet air is of low enough moisture content. It is common for the alarm to be on immediately after startup. The length of time required for the alarm to go out depends somewhat on how long the unit was idle. It could take as long as one complete cycle (4 hours) to stop the alarm.

8. When the Humidity and Temperature Alarms both indicate normal conditions, SLOWLY open the flowmeter outlet isolation valve. When the valve is fully open, check that the airflow rate is within the design limit of the unit.

NOTE

This dehydrator is fully automatic and is designed for continuous duty. However, this does not mean that it should be operated with no attention whatsover. GOOD ENGINEERING PRACTICE DEMANDS THAT AN OPERATING LOG BE MAINTAINED. Because of the cycle times involved, it is strongly recommended that operating data be logged on an hourly basis. If accurate logs are maintained, they can be of great assistance in determining the cause of a malfunction, and can even predict a malfuction before the dehydrator begins to deliver wet air.

NOTE

In order to keep operating time even, it is recommended that units be rotated every 200 operating hours or weekly. This rotation will also tend to keep the standby unit dry.

551-4.5.4.4 Monitoring. The following controls and indicators are provided to monitor dehydrator performance:

a. Power-On light is lit when Power-On switch is ON.

b. Humidity Alarm light is lit when the moisture content of the air being delivered by the dehydrator rises above a preset point (normally -30° F dewpoint at 80 lb/in^2)

c. Refrigeration Temperature Alarm light is lit when the refrigerated air temperature rises above 70° F or below 34° F.

d. Chamber Reactivating lights are lit one at a time to indicate that the chamber is in its reactivation period, while the extinguished light shows that its chamber is on drying service.

e. Heater-On light is lit when the heater relay is energized.

f. The Humidity Alarm consists of the light and a buzzer. The Humidity Alarm is also provided with an external output.

g. A delay timer in the electrical enclosure prevents actuation of the Temperature Alarm during the normal cool down time at the beginning of operation.

h. The Temperature Alarm consists of the light and a buzzer. The Temperature Alarm is also provided with an external output for remote side indication.

i. Loss of purge flow energizes a set of external contacts.

j. Elapsed Time Indicator indicates cumulative operating time.

k. Humidity Alarm remote connection provides a 110-volt signal to an external remote alarm of the user’s choice and installation. The connection is energized when the outlet air moisture level goes above design limits.

l. Temperature Alarm remote connection provides a 110-volt signal to an external remote alarm of the user’s choice and installation. The connection is energized when the temperature of the air leaving the refrigerated stage goes outside design limits.

m. Purge Flow Alarm remote connection provides a 110-volt signal to an external remote alarm of the user’s choice and installation. The connection is energized when purge flow drops below design limits. (A time delay prevents activation of the alarm when purge flow drops at chamber shift.)

n. Chamber Temperature controllers are provided, one for each chamber. They indicate chamber reactivation temperature and control the chamber heaters to limit maximum temperature.

o. Temperature Indicator/Alarm indicates the temperature of the air leaving the refrigerator evaporator, and energizes an alarm system if the temperature goes outside design limits. In normal operation, the temperature should run between 34° F and 65° F.

p. Humidity Alarm controller measures the output of the Humidity Alarm Sensor and energizes an alarm system if the humidity level of the outlet air exceeds the design limit (generally -30° F dewpoint).

q. Inlet pressure gauge indicates the pressure of the air entering the dehydrator. In normal operation, it should run between 80 lb/in^2 g and 150 lb/in^2 g.

r. Outlet and Purge pressure gauge indicates the pressure of either the air leaving the dehydrator or the air to the purge flowmeter.

s. Purge flowmeter indicates the rate of airflow through the purge system.

551-4.5.4.5 Securing. The unit may be secured at any time with no short-term ill effects. However, for maximum service life from desiccant and heaters, it is highly preferable to secure the unit toward the end of the cooling portion of the reactivation cycle (time: 1-1/2 to 2 hours or 3-1/2 to 4 hours). Use the following procedure to secure the dehydrator:

1. Close the flowmeter outlet isolation valve.
2. Turn the Power-On switch OFF. All indicator lights will go out and the refrigeration compressor and its fan will stop. The unit is now in STANDBY.
3. Secure the condenser cooling water supply. The unit is now OFF.

551-4.5.5 Condenser-Filters. Condenser-filters are phasing out Type I LPAD’s. Condenser-filters are a much simpler and more reliable design, but also have a slightly higher dewpoint than Type I LPAD’s.

551-4.5.5.1 Functionally Condenser-filters consist of a chill-water heat exchanger, filters, automatic drain traps, and an alarm system. The chill water heat exchanger cools the air and condenses out moisture. Condenser-filter dehydrators use 3-4 GPM of chill-water supplied from the ship’s chill-water system. After the chill-water heat exchanger, the air flows through the filters, past the temperature sensor, and to the LP air system. Both the condenser section and filter section are drained by automatic drain traps. An alarm activates when air outlet reaches 55° F, but is de-energized during periods of no air flow by means of an interlock with the LPAC controller.

551-4.5.5.2 The benefits of this simpler design are:

a. Reduced maintenance due to fewer moving parts.
b. Cooling medium is chilled water vice refrigerant for Type I.
c. Lower electrical load.

551-4.5.6 LP AIR DEHYDRATOR MAINTENANCE. Scheduled maintenance of LP air dehydrators shall be in accordance with PMS requirements. The following is provided for INFORMATION ONLY.

1. Daily:

a. Check applicable running/ power on lights, flowmeter reading, cooling water temperatures, heater temperatures, and outlet air temperatures (as applicable) for proper operation.

b. Observe dehydrator filter element pressure drop for element replacement.

c. Periodically blowdown and clean the condenser water strainer.

d. Blowdown types I and III dehydrators. Dump valve if more than 1/2 pint of water drains out; the automatic feature is not working.

e. Check purge pressure and the free movement of the purge flowmeter float of types II and III dehydrators.

2. Weekly: Blowdown inlet separator, prefilter, and trap dump valve of dehydrators by opening the manual drain valve.

3. Monthly:

a Check outlet air moisture content. Dewpoint should be below -40° F at 80 lb/in^2 for both type II and type III dehydrators, and below 40° F at 80 lb/in^2 for the type I dehydrator. Excessive dewpoint indicates a malfunction.

b Check types II and III dehydrator inlet and outlet filters and purge filter. Replace filter elements if necessary.

4. Quarterly:

a Clean the water tubes of refrigerant condenser.

b Disassemble and clean inlet and interstage separators and purge solenoid valves.

5. Annually:

a Remove and calibrate pressure gauges. Adjust to give maximum error 2 lb/in^2 (1 percent of full scale).

b Disassemble the desiccant chambers. Clean assembly of dust, oil, and dirt. Replace desiccant if significantly powdered, burned, or discolored with oil carry-over.

c Remove desiccant chamber check valves. Discard and replace with new items. Adjustment and repair of dehydrators and components should be accomplished according to the appropriate equipment technical manuals.

551-4.5.7 LP AIR DEHYDRATOR TESTING. Specific procedures for testing LP air dehydrators shall be as follows.

551-4.5.7.1 Air Quality Testing. The purpose of this test is to daily monitor the dry air dewpoint at the dehydrator(s) outlet. A different dehydrator is selected each day, on a rotating basis. The test is conducted with a low-pressure frost point indicator MIL-I-24144.

551-4.5.7.1.1 The dewpoint reading at the dehydrator(s) shall be -40° F at 80 lb/in^2 g or lower for both types II and III dehydrators, and 40° F at 80 lb/in^2 g or lower for the type I dehydrator. The dewpoint reading at the dehydrator(s) is compared with previous readings. If degradation is apparent, corrective action can be performed before a NO GO condition. The dewpoint reading at the air control panel inlet shall be below -40° F at 80 lb/in^2 g. A dewpoint reading above -40° F at 80 lb/in^2 g at the air control panel, while the dewpoint reading at the dehydrator(s) is at or below -40° F at 80 lb/in^2 g, indicates a leak or unauthorized cross connection between the vital and ships' service system and the electronics dry air branch downstream of the dehydrator(s).

551-4.5.7.2 Testing of Self-Draining Automatic Trap Drain Lines. Prefilters and separators in low pressure dehydrator units are equipped with self-draining automatic traps. Entrained water, oil droplets, and condensed moisture filtered out by the prefilter, or separated by the separator, drains down and settles in the self-draining automatic trap chamber. A self-draining automatic trap is also installed on the bottom of each air receiver. When the condensate (liquid) reaches a designed level/quantity (refer to applicable dehydrator or self-draining automatic trap technical manual), the self-draining automatic trap opens, and the trapped condensate drains through piping to the machinery space bilge area or a deck drain.

551-4.5.7.2.1 The self-draining automatic trap is equipped with a manual drain line and valve connected to the bottom of the trap chamber to provide emergency draining in the event of automatic draining failure. The manual drain is also used for periodic testing and complete draining of the trap chamber to prevent excessive accumulation of heavy settlements.

551-4.5.7.2.2 Common problems associated with self-draining automatic traps are: malfunction of the automatic drain feature due to wear or failure of internal parts; accumulation of sludge, dirt, and so forth, to a level that prohibits proper automatic operation; and clogged drain lines. Any of these problems will permit the self-draining automatic trap to fill with condensate and back up into the unit that is drained (prefilter, separator, air receiver). The condensate that should be removed remains in the airstream.

551-4.5.7.2.3 The purpose of this test requirement is to ensure the self-draining automatic trap and manual drain lines are not clogged. The test is conducted on each self-draining automatic trap as follows:

1. Open the manual drain valve
2. Catch and measure the liquid that flows from the manual drain line (some liquid should drain). The drained liquid shall be less than the quantity specified in the applicable dehydrator or self-draining automatic trap technical manual.

551-4.5.7.3 Testing and Placing Reserve Electronics Dry Air Branch Dehydrator in Service. Ships with two dehydrator configurations normally have both dehydrators in one machinery space. Normal system operation is one dehydrator in service and one in reserve. Ships with four dehydrator configurations have two dehydrators installed in one fwd machinery space and two installed in one aft machinery space. Normal system operation is one fwd dehydrator and one aft dehydrator in service, with one fwd dehydrator and one aft dehydrator in reserve.

551-4.5.7.3.1 The purpose of this test requirement is to rotate the in-service and reserve dehydrator(s) weekly to permit equipment PMS on the dehydrator placed in reserve and to distribute operating time evenly between dehydrators. Allow the dehydrator to complete one operation cycle (4 hours), and make sure the dehydrator outlet dewpoint is -40° F at 80 lb/in^2 g (.000015 pounds of water per pound of air) or lower before the dehydrator is placed on the line (opening of dehydrator outlet valve). The dewpoint is measured by using a low-pressure frost point indicator MIL-I-24144, connected to the dehydrator dewpoint sample connection.

551-4.5.8 HP AIR DEHYDRATORS. The HP (3,000 lb/in^2 /5,000 lb/in^2) air dehydrator, furnished according to MIL-D-17847, is a semi-automatic, operator-controlled, self-activating, heat-reactivated, dual-tower desiccant type unit. The HP dehydrator operates on the ships' 440-volt, 60-cycle, 3-phase power supply with an effluent air dewpoint rating of -60° F at the nominal operating pressure of the system. The basic operating principles of the HP air dehydrator and the LP (type II) desiccant air dehydrator are very similar (see Figure 551-4-29). The following different physical characteristics exist:

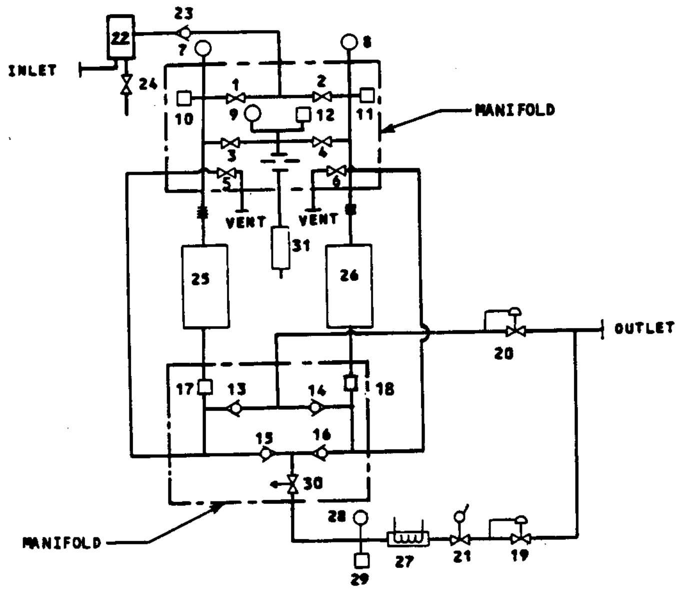


Figure 551-4-29 HP Air Dehydrator Flow Diagram (Sheet 1 of 2)

Component Identification

Item number	Description
1	Left tower flow selector valve
2	Right tower flow selector valve
3	Left tower reactivating air exhaust valve
4	Right tower reactivating air exhaust valve
5	Left tower depressurization valve
6	Right tower depressurization valve
7	Left tower pressure gauge
8	Right tower pressure gauge
9	Reactivation air pressure gauge
10	Number 1 pressure switch
11	Number 2 pressure switch
12	Number 3 pressure switch
13 thru 16	Check valve
17 and 18	Afterfilters
19	Reactivating air reducing valve
20	Back pressure regulating valve
21	Reactivating air solenoid stop valve
22	Prefilter
23	Inlet check valve
24	Prefilter drain valve
25	Left dehydration tower
26	Right dehydration tower
27	Reactivating air heater
28	Reactivating air temperature gauge
29	Reactivating air high temperature switch
30	Reactivating airflow control valve
31	Muffler

Figure 551-4-29 HP Air Dehydrator Flow Diagram (Sheet 2 of 2)

a. Pressure ratings: HP versus LP.

b. Valve operation: HP desiccant dehydrators are semi-automatic components (tower switching and drain valves are manually operated) while the LP desiccant dehydrator components are fully automated.

c. Valve operating time: The valve opening and closing times on HP desiccant dehydrators are relatively much more critical than on LP desiccant dehydrators. Sudden loading/unloading of high-pressure in the desiccant bed causes dusting of the desiccant granules and clogging of downstream components. All manual opening and closing of valves on HP desiccant dehydrators shall be done very slowly.

d. Air quality testing: The dewpoint reading at the HP desiccant dehydrator discharge shall be according to paragraph 551-1.7. Consult the applicable manufacturer's technical manual for detail operation and maintenance of the dehydrators.

e. There are two possible sources of reactivation air for HP dehydrators. In addition to the internal purge air source for reactivating HP dehydrator desiccant, many HP dehydrators also have an external purge connection to give the option of purging the HP dehydrator with air from the LP dry air system. When this option is available, ships are typically configured to utilize the external purge source since internal purge adds a significant load to the HP air system.

551-4.5.9 DEHYDRATOR DESICCANT. The dehydrator dessicant is discussed in the following paragraphs.

551-4.5.9.1 Type and Procurement. The various types of dehydrator desiccant in use throughout the fleet are being replaced, in both the LP and HP desiccant type dehydrators, with activated alumina beads in 1/8-inch diameter spheres. The NSN for this desiccant is 9G-6850-00-738-1672. This change in desiccant is intended to reduce dusting which clogs filters and other system components.

551-4.5.9.2 Loading. Before installing the new desiccant, refer to the applicable manufacturer's technical manual for instructions on securing and disassembling the dehydrator towers (observe all safety notes). Remove the old desiccant using a vacuum device, or pour out the old desiccant by turning the tower upside down when possible. Clean the filter housing and retainer assemblies using an approved solvent meeting FED Spec P-P-680 or equivalent. Ensure that all filters are cleaned or replaced as required and that they all are properly replaced. Use dry, clean air for drying all surfaces and components.

551-4.5.9.2.1 The desiccant towers should be filled to the level specified in the applicable technical manual with activated alumina in 1/8-inch diameter spheres. DO NOT USE DESICCANT WHICH HAS BEEN POWDERED OR CRUSHED DURING SHIPPING. The towers should be filled a few (3 to 6) inches at a time, and the outside of the tower should be tapped with a rubber mallet to settle the desiccant each time desiccant is added. DO NOT TAP THE DESICCANT ITSELF.

551-4.5.9.2.2 After the towers are completely filled, tap each tower with a rubber mallet for about 3 minutes and then refill each tower to the proper level. DESICCANT SHALL BE PROPERLY PACKED AND HELD IN PLACE TO PREVENT MOVEMENT AND POWDERING.

551-4.5.9.2.3 Ensure that all retainers and springs provided are in good condition and secured properly before closing the desiccant chamber. Reassemble the towers according to the procedure outlined in the applicable manufacturer's technical manual.

551-4.5.9.3 Preservation. The dehydrator back pressure regulating valve should be set to maintain the proper back pressure according to the applicable dehydrator technical manual. If the back pressure reduces, the resulting increase in air velocity through the desiccant chamber causes accelerated desiccant dusting and clogging of downstream components. Reduced back pressure also increases the amount of moisture that may be removed from the airstream which, in turn, causes overloading of the desiccant bed and moisture carryover to the system downstream.

551-4.5.9.3.1 Rapid opening and closing of dehydrator valves during tower changeover from service to reactivation, or from reactivation to service, can cause dusting of the desiccant and its carryover to downstream components. This is of primary importance in the HP desiccant dehydrators. The maximum pressurization/depressurization rate is 200 lb/in^2 per second (15 seconds to completely open/close a valve for a 3,000 lb/in^2 system).

551-4.5.9.3.2 The desiccant used shall be heated to a minimum temperature to effectively drive off the moisture from the moisture-laden desiccant during the reactivation cycle. Too low a temperature does not drive off adequate moisture from the desiccant, and too high a temperature results in a shortened desiccant life and also in higher failure rates of the dehydrator components. The temperature controller shall be set properly and as specified in the applicable manufacturer's technical manual. This temperature setting is generally 400° F.

551-4.5.9.3.3 Satisfactory air drying by a dehydrator requires that a desiccant tower be fully reactivated before placing it in service. If a dehydrator has not been in service for several days, it is recommended that, before use, the tower designated to be used be put through a complete reactivation cycle. Except in the case of a malfunction, shutting down, interrupting, or switching towers before the full completion of a reactivating cycle should be avoided. Continuous flow of purge air shall be maintained during the reactivation cycle. Interruption of power during a reactivation cycle shuts off purge air and can cause overheating and failure of heater elements in addition to inadequate desiccant drying.

551-4.5.9.3.4 Some HP air systems include a bypass dehydrator. Generally, this bypass is not equipped with protective filters. The desiccant used in this bypass is a prepackaged disposable cartridge which shall be replaced after use. DO NOT USE LOOSE DESICCANT IN THE BYPASS DEHYDRATOR. USE ONLY THE CORRECT DISPOSABLE DESICCANT CARTRIDGE.

551-4.6 DRY AIR CONTROL PANELS

551-4.6.1 Air control panels according to NAVSHIPS dwg 810-1385925 are installed in electronic equipment spaces that require dry air pressurization. Air control panels are supplied in the following four types:

a. Type I. Outlet Pressure: 0 to 30 lb/in^2 g. Flow rate: 0 to 10 scfm.

b. Type II. Outlet Pressure: 25 to 60 lb/in^2 g. Flow rate: 0 to 10 scfm.

c. Type III. Outlet Pressure: 75 lb/in^2 g. Flow rate: 0 to 15 scfm.

d. Special. For special applications where types I, II, or III cannot meet the pressure or flow rate requirements of the user equipment.

551-4.6.2 The air control panel reduces and regulates the dry air for electronics distribution system pressure (80 to 125 lb/in^2 g) to the pressure required by the user equipment. See electronic user equipment/system technical manual for dry air pressure requirements. These pressures vary from 0.3 to 75 lb/in^2 g. Flow rates vary from 0 to 125 scfm. The type of air control panel installed depends upon the electronic user equipment pressure and flow rate requirements.

551-4.6.3 The panel outlet pressure (user equipment pressure) can be adjusted within the outlet pressure range of the type panel installed. For example, the type I panel can be adjusted/set to provide a regulated outlet pressure from 0 to 30 lb/in^2 g.

551-4.6.4 The flow rate cannot be controlled by the air control panel. Flow rate is controlled by regulator devices in the user equipment. See user equipment/system technical manuals for required flow rates. Flow rating of the air control panel indicates that the panel is limited to the specified flowmeter range. For example, the type I panel can pass between 0 to 10 scfm of air and still maintain pressure regulation for outlet pressures set between 0 and 30 lb/in^2 g.

551-4.6.5 An air control panel outlet pressure relief valve provides overpressurization protection for user equipment. One air control panel is often installed for two or more equipments requiring the same pressure, provided that the total flow rate is within the panel flowmeter range. Each panel is equipped with a sampling connection, flow meter, pressure gauges, and valves to permit user equipment personnel to monitor air supply to their equipment (see Figure 551-4-29). Humidity indicators are also provided on older design panels; however, they have been eliminated from newer designs due to the inability to maintain accurate calibration of the alarm set point.

551-4.7 AUTOMATIC VALVES

551-4.7.1 GENERAL. The automatic valves used in compressed air systems perform various necessary functions. They control pressure or flow and may be self-actuating or remote operated valves. Some of the more common self-actuating type valves are pressure reducing valves, pressure relief valves, priority valves, and safety-stop check valves. The remote operated valves are normally solenoid air actuated (quick operating or pressure rate-controlled) type valves.

551-4.7.2 PRESSURE REDUCING VALVES. Pressure reducing valves maintain a constant pressure, within accuracy limits, downstream of the valve. The valve maintains this constant delivered pressure during flow and supply pressure variations by automatically throttling, or shutting off flow as necessary based on a signal feedback of the downstream pressure. Reduced pressure is proportional to the change of flow through the main line of the valve. A pressure tapping orifice off the main line, feeds a void under a loaded diaphragm. The diaphragm may be loaded by a set spring or pressurized dome. The diaphragm is connected to the control valve which allows air to flow through the valve main line. A typical pressure reducing valve is shown in Figure 551-4-30. This is a diaphragm-type valve actuated by air pressure sealed in a dome which drives the valve stem. The valve operates on the principle of balancing outlet pressure with dome pressure across the diaphragm.

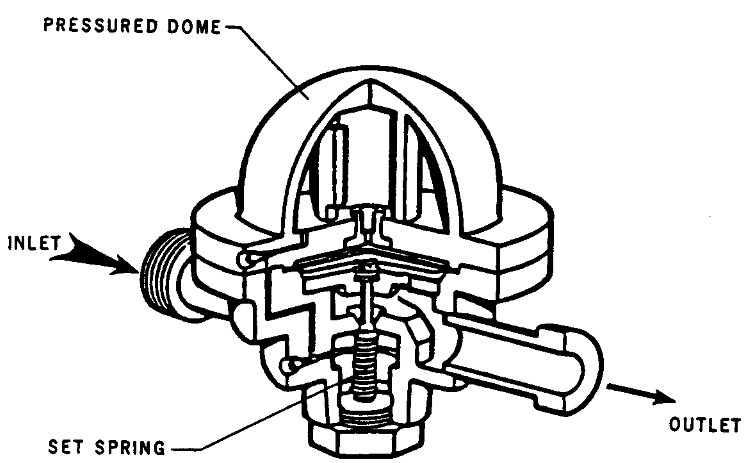


Figure 551-4-30 Standard 4,500 lb/in^2 Air Reducing Valve

551-4.7.3 PRESSURE RELIEF VALVES. Pressure relief valves are installed in systems in which an excessive pressure may cause damage to the system or equipment or may injure personnel. The pressure relief valve is an automatic device which upon sensing excessive pressure actuates a release, safely discharging the pressure from the system in a controlled manner. Upon sensing a drop in pressure below the excessive pressure point, the release will close, thus returning the valve to normal operation.

551-4.7.3.1 The pressure relief valve design is generally of two types: direct actuation and remote sensing. The direct actuation variety has a spring or weight loaded disc. The compressed air acts directly upon the underside of the disc. If the pressure of the compressed air does surpass the setpoint pressure, the disc will unseat, discharging the excessive pressure. The setpoint pressure is adjusted by spring tension or the amount of weight loaded against the disc. As the air pressure under the disc decreases, the disc will move to reseat itself, returning to the normal operation position. The remote sensing variety utilizes a pressure sensing device electrically connected to a local solenoid actuated pressure relief valve. A typical relief valve is shown in Figure 551-4-31.

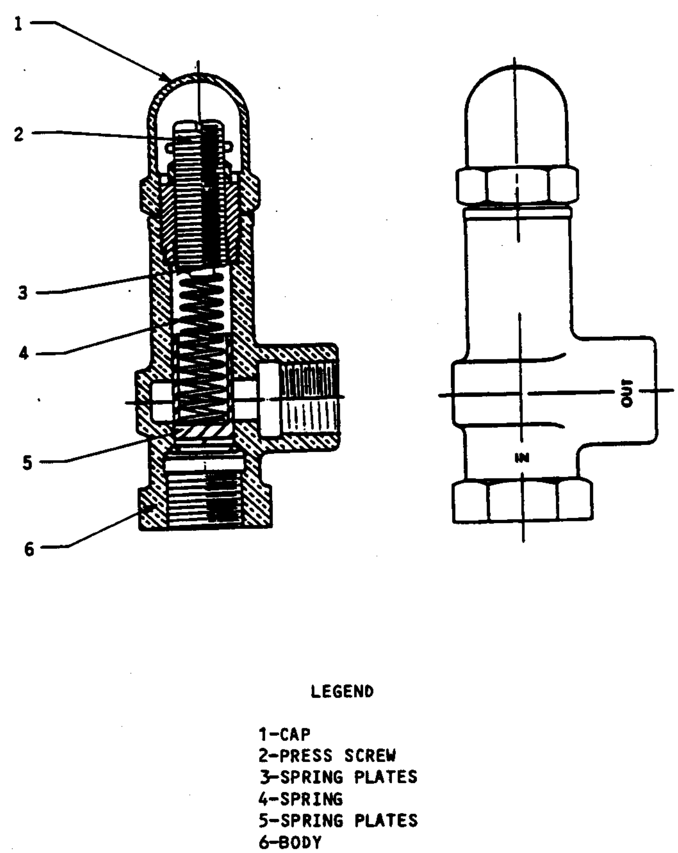
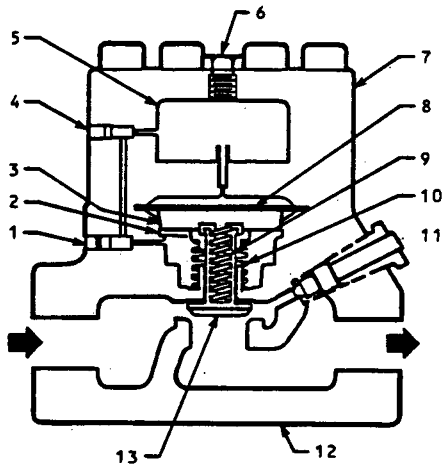


Figure 551-4-31 Typical Direct Actuation Relief Valve

551-4.7.4 SAFETY-STOP CHECK VALVES. Safety-stop check valves are installed in hose supply lines to prevent injury to personnel due to whipping hose in the event of a hole rupture. This is accomplished by quickly and automatically shutting off the flow under certain excess flow conditions. This type of valve is normally diaphragm actuated with the diaphragm connected directly to the control valve. An air pressurized dome above the diaphragm closes the control valve while a spring acts to open the valve. Downstream pressure against the valve face added with the spring force total to act against the diaphragm. This total value is greater than that of the pressurized dome; therefore, the valve remains open. If downstream pressure is removed, as in a hose rupture, the pressurized dome forces the valve closed. The valve will remain closed until the downstream casualty is repaired and the reset needle valve bypass is opened, repressurizing downstream of the control valve. A typical safety-stop check valve is shown in Figure 551-4-32.



1 - BODY NEEDLE VALVE
2 - VALVE WASHER
3 - DIAPHRAGM PLATE
4 - DOME NEEDLE VALVE
5 - PRELOADED DOME PRESSURE
6 - GAUGE CONNECTION
7 - DOME
8 - DIAPHRAGM
9 - DIAPHRAGM SPRING
10 - VALVE SPRING
11 - RESET NEEDLE VALVE
12 - BODY
13 - VALVE

Figure 551-4-32 Typical Safety Stop-Check Valve

551-4.7.5 PRIORITY VALVES. A priority valve is installed in the cross connection from the vital service air main to the nonvital service air main. This valve reduces or restricts airflow to nonvital service to maintain supply to the vital services. The priority valve inlet is the vital service side while discharge is to the nonvital service main (see Figure 551-4-33). Air from the vital services LP air main enters the valve from the left. The air flows through the sensing ports to the underside of the diaphragm and piston. When the pressure is above the set pressure, it overcomes the spring force and moves the piston upwards. The ball cage is connected to the piston and the poppet retained with the ball cage. As the piston rises, the poppet is lifted from the seat and air flows through the valve to the ships' service LP nonvital air main.

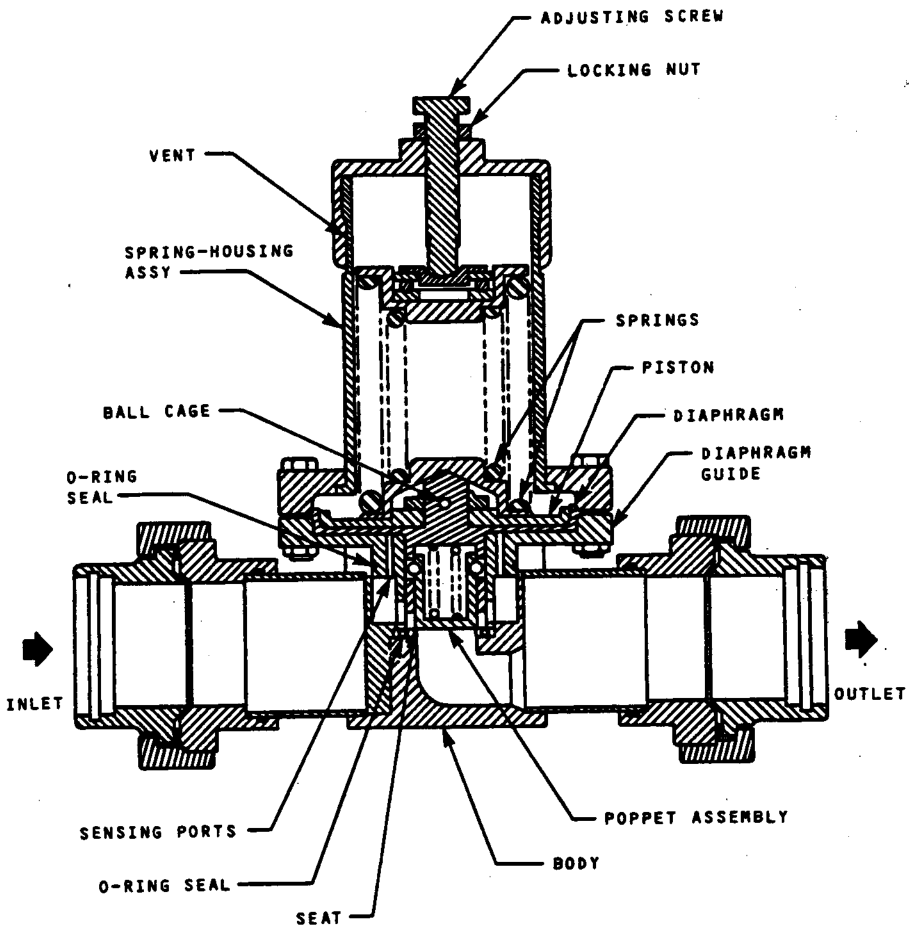


Figure 551-4-33 Typical Priority Valve

551-4.7.5.1 When the vital services air main pressure drops, the springs overcome the pressure under the piston and the springs drive the piston, ball cage, and poppet down, reducing the flow. This allows the vital air main to recover pressure. Depending on upstream pressure and downstream demand, the valve will reach a condition of equilibrium where the upstream pressure on the piston balances the spring load. The adjusting screw provides a means of varying the spring load to set the closing pressure. The closing pressure is 85 lb/in^2 . A locking nut is provided to lock the screw in position after adjustment.

551-4.7.6 REMOTE OPERATED VALVE TYPES. Remote operated valves are installed when operation of the valve from a distant control station is desirable. These valves are normally solenoid-operated with a local manual override.

551-4.7.6.1 Quick Opening Type. Quick-opening valves are installed where an immediate surge of compressed air is required. An example of this is in the ballast-deballast system of some surface ships or submarines. Some valve types utilize upstream pressure for actuation, activated by a solenoid valve responding to an electrical signal from a switch, thermostat, or other device. When the solenoid valve opens in a branch line upstream, pressure passes to open the quick-opening valve. A typical quick-opening, remote-operated valve with a direct manual override is shown in Figure 551-4-34.

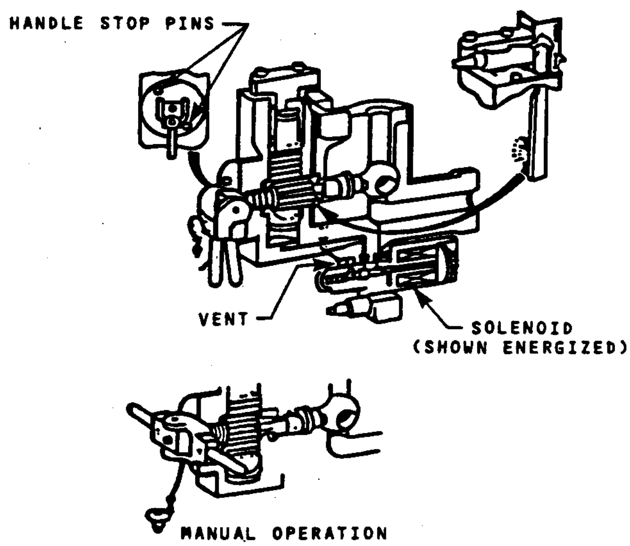


Figure 551-4-34 Typical Quick-Opening, Remote Operated Valve with Direct Manual Override

551-4.7.6.2 Pressure Rate Controlled Type. The pressure rate controlled type valve was developed to reduce the possibility of compression ignition (dieseling). This valve contains a pressure equalization line which allows high-pressure to bypass the main valve, equalizing downstream pressure with upstream pressure. This action prevents high upstream pressure from slamming downstream of the valve. The main valve will open when upstream and downstream pressures are relatively the same. Typical arrangement and use of solenoid actuated, remote operation, pressure rate controlled valves are shown in Figure 551-4-35 and Figure 551-4-36.

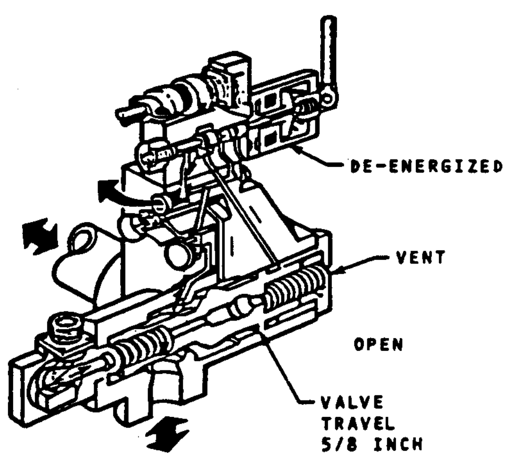


Figure 551-4-35 Typical Solenoid Actuated, Remote Operated, HP Air Stop Valve with Override on Pilot

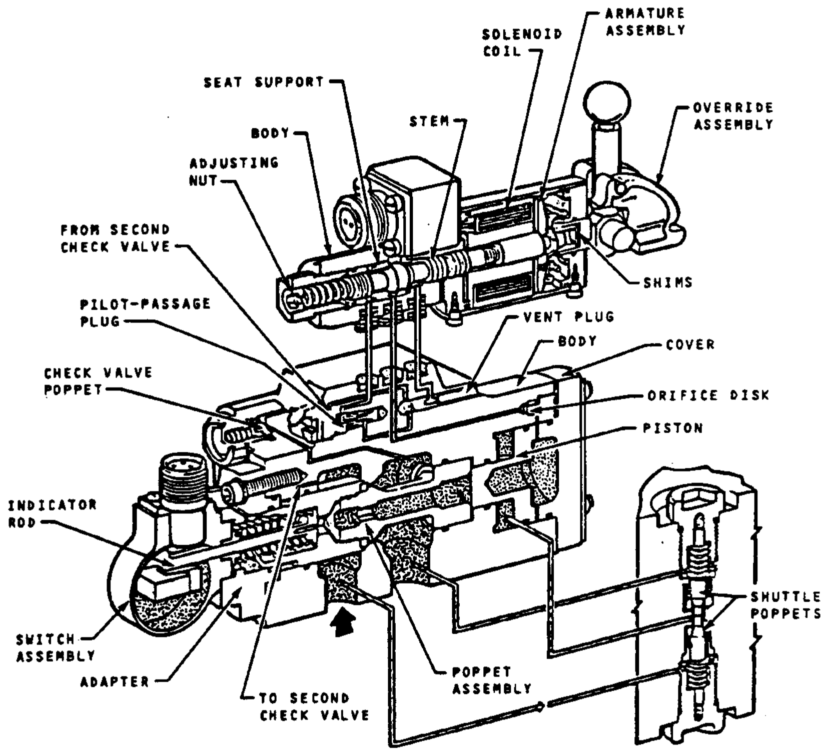


Figure 551-4-36 Typical Air Solenoid Valve for Air Banks and Missile System

551-4.7.7 BLEED AIR REGULATING VALVES. The function of a typical bleed air regulating valve is depicted in Figure 551-4-37. Inlet air pressure from the valve body can be directed to either side of the control piston, which in turn positions the butterfly (vane) through the actuator linkage. When there is no line pressure, the spring under the control piston tends to close the butterfly. The spool and sleeve assembly (4-way valve) directs the upstream air pressure from the valve body to the actuator control piston. Positioning of the spool and sleeve assembly is accomplished in the diaphragm-operated control section. A spring-balanced piston assembly, working against the downstream static sense pressure across the diaphragm, positions the spool. Response rate is established by a fixed rate chamber orifice. The control pressure calibration screw can be adjusted to set the downstream pressure.

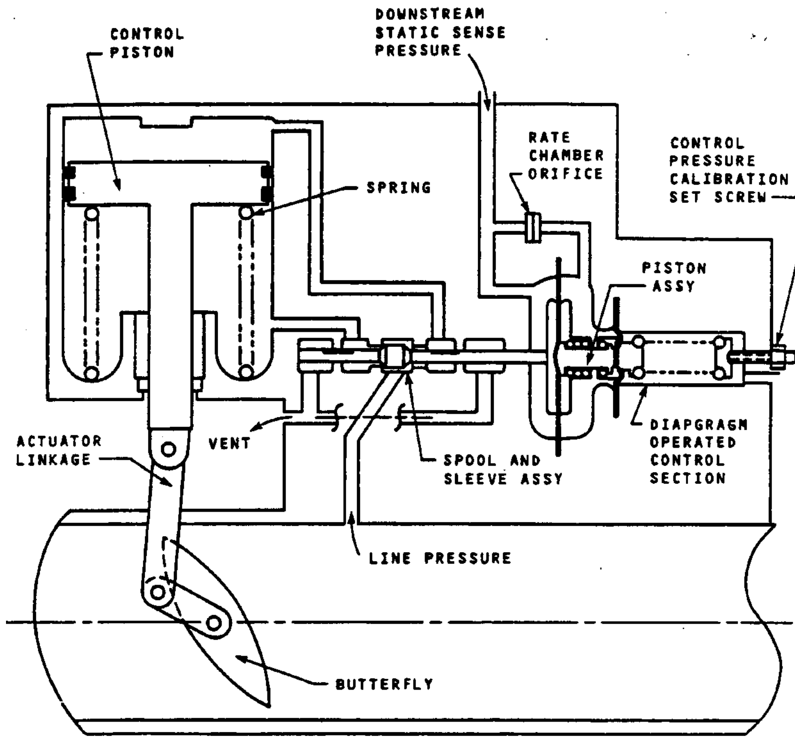


Figure 551-4-37 Typical Bleed Air Regulating Valve (Functional Schematic)

551-4.8 COMPRESSOR OPERATING DATA LOG SHEET

551-4.8.1 It is recommended that a log be kept by the operator and readings be taken and recorded at established intervals. See sample Compressor Operating Data Log Sheet, Figure 551-4-38. For extended operation, a data log sheet should be filled out during every watch. A log is beneficial not only from the operational and maintenance standpoints, but also serves as a guide in detecting unusual and inefficient operating conditions. Depending on the ships' air system demand, it is likely that the actual operating time on each compressor of a multicompressor installation will vary considerably. In order to obtain the best service from each compressor, it is advisable to equalize the operating time over each quarterly period. This can be done by noting the hours recorded in the log (from the Operating Hours Meter if installed) and then changing the operating sequence of the units accordingly.

OPERATING DATA LOG SHEET

USS ________________ (SSBN ________________) HPAC NO. __________ DATE ____________

	SHUT-DN	MIN	NORMAL	MAX	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
FRAME OIL PRESSURE (PSIG)	14 a	14	25*-50*	50																								
PRESSURE (PSIG) 1st STAGE	60 b	32	40-45*	59																								
2nd STAGE	330 b	209	250-270*	324																								
3rd STAGE	1225 b	940	1055-1075*	1200																								
4th STAGE h	[illegible]	4200	4200-4675*	5100																								
TEMP (°F) 1st STAGE-suct		49	84	122																								
1st STAGE-disch	430 a		336	415																								
2nd STAGE-suct			122																									
2nd STAGE-disch	430 a		374	415																								
3rd STAGE-suct			119																									
3rd STAGE-disch	430 a		356	415																								
4th STAGE-suct			119																									
4th STAGE-disch	430 a		376	415																								
FINAL DISCH TEMP		115		125																								
CLG WTR OUTLET TEMP	125 a	95	95-115*	120																								
CRANKCASE OIL TEMP		135		170*																								
CRANKCASE OIL LVL		LOW	MIDDLE	HIGH																								
CYL LUBE OIL LVL		1/2		FULL																								
CLG WTR PMP DISCH PRGSS		25		175																								
CLG WTR INLET TEMP				95																								
LUB FLOW RATE (DROPS/MIN) 1st STAGE		10 d	11	15 e																								
2nd STAGE		10 d	11	15 e																								
3rd STAGE		10 d	13	15 e																								
4th STAGE		10 d	13	15 e																								
CUNO AIR FILTER	DRAIN BOTH EVERY HR. g																											
MOISTURE SEP FLASK	DRAIN BOTH EVERY HR.																											
DHYR PREFILTER	DRAIN EVERY TOWER CHGE-OVER																											
DHYR BY-PASS CARTRIDGE	REPLACE CARTRIDGE f																											
CONDENSATE DRAINAGE	MUST BE OBSERV.-6 MIN CYCLE																											

* CIRCLE LOG VALUES WHICH ARE OUTSIDE THE NORMAL RANGE LIMITS INDICATED IN RED.

a - WILL SHUT DOWN AUTOMATICALLY.

b - RELIEF VALVE LIFTS.

c - WILL CAUSE WET AIR TO BE SUPPLIED TO BANKS, RESET BACK PRESSURE CONTROL VALVE ON DEHYDRATOR.

* FOR WORTHINGTON CLASS AA, 13.8 CFM 4500 PSI AIR COMPRESSOR TECH MANUAL 319-0738 (NAVSEA 0349-073-0886)

d - INADEQUATE LUBRICATION BELOW THIS RATE.

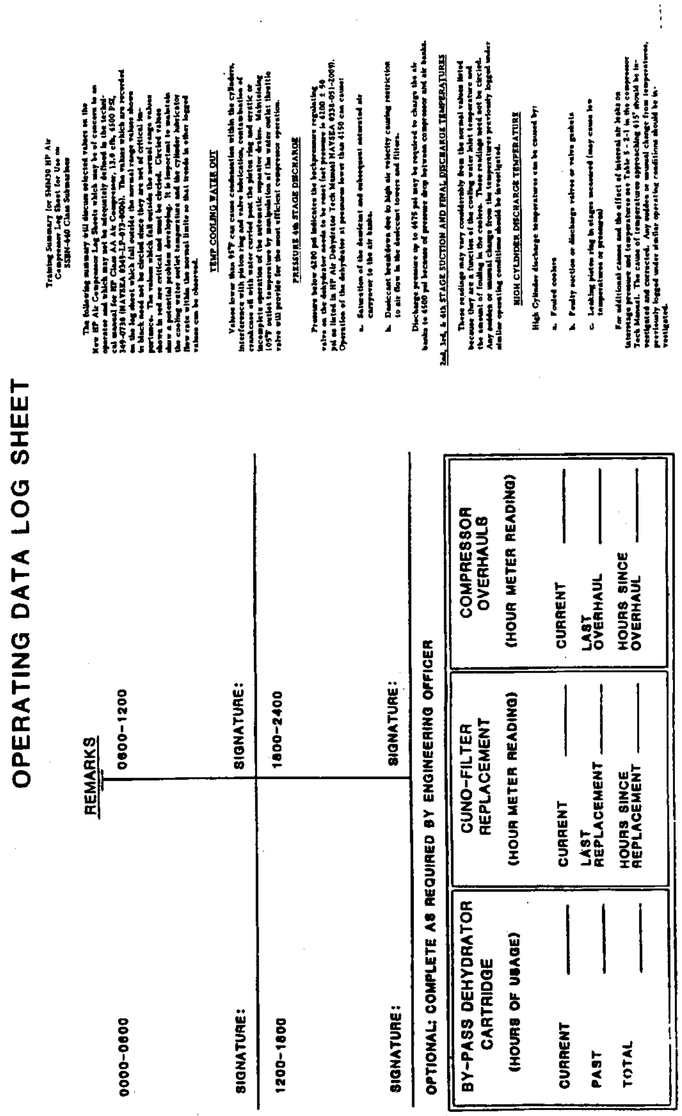
e - CAUSES EXCESS CARBON & OIL CARRYOVER ABOVE THIS RATE.

f - WHEN USED, REPLACE CARTRIDGE AFTER 4 HRS-TWO COMPRESSOR USE OR 8 HRS SINGLE COMPRESSOR USE. FOR #3 HPAS COMP REPLACE EVERY 8 HRS OF THE COMPRESSOR USE.

g - REPLACE ELEMENT EVERY 200 HRS COMPRESSOR USE OR MONTHLY, WHICHEVER FIRST.

h - DISCHARGE PRESSURES BETWEEN 4675 lb/in^{2}g AND RELIEF VALVE SETTING MAY BE DUE TO DESICCANT PLUGGING OF FILTERS.

Figure 551-4-38 Typical Compressor Operating Data Log Sheet (Sheet 1 of 2)



OPERATING DATA LOG SHEET

REMARKS

0000-0600

0600-1200

SIGNATURE:

SIGNATURE:

1200-1800

1800-2400

SIGNATURE:

SIGNATURE:

OPTIONAL: COMPLETE AS REQUIRED BY ENGINEERING OFFICER

BY-PASS DEHYDRATOR CARTRIDGE (HOURS OF USAGE)	CUNO-FILTER REPLACEMENT (HOUR METER READING)	COMPRESSOR OVERHAULS (HOUR METER READING)
CURRENT ____	CURRENT ____	CURRENT ____
PAST ____	LAST REPLACEMENT ____	LAST OVERHAUL ____
TOTAL ____	HOURS SINCE REPLACEMENT ____	HOURS SINCE OVERHAUL ____

Figure 551-4-38 Typical Compressor Operating Data Log Sheet (Sheet 2 of 2)

SECTION 5.

PERFORMANCE MEASUREMENTS AND EFFICIENCIES

551-5.1 TIME REQUIRED TO PUMP UP A RECEIVER OR FLASK

551-5.1.1 It is often desirable to know the approximate time required for a compressor to pump up a receiver or flask to a certain pressure. The following formula can be used for this purpose.

$T = V(P_2 - P_1)/P_A\ (PD)(VE)$

in which:

T = Time required to pump up receiver or flask from pressure P_1 to pressure P_2 in minutes.

V = Volume of receiver or flask, in ft^3 =

Vol in gals / 7.48

P_1 = Initial pressure in receiver of flask, in lb/in^2 a.

P_2 = Final or desired pressure in receiver of flask, in lb/in^2 a.

P_A = Atmospheric pressure, in lb/in^2 a. Use the value 14.7 lb/in^2 a pressure if at sea level. For other altitudes the correct atmospheric pressure should be substituted.

PD = Piston displacement of compressor, in ft^3 /min.

VE = Average volumetric efficiency of compressor, as a decimal. If VE is unknown, a value of 0.8 may be assumed. The VE is not constant, but will decrease as the discharge pressure increases. Therefore, the average should be used.

(PD)(VE) = Actual delivery of compressor, in ft^3 /min. If this value is known, it may be substituted in the formula for the two terms PD and VE.

551-5.1.2 This formula will give only approximate results, since factors such as temperature changes are not considered in the formula and cannot be accurately measured without elaborate apparatus. In most cases, these factors would tend to slightly decrease the pump up time from that shown by the formula.

551-5.2 REQUIRED PISTON DISPLACEMENT TO PUMP UP A RECEIVER OR FLASK IN A CERTAIN TIME

551-5.2.1 If it is desired to know the piston displacement required to pump up a receiver or flask in a certain time, the same formula may be rewritten as follows:

$$PD = V(P_2 - P_1)/P_A (T)(VE)$$

551-5.3 COMPRESSOR CAPACITY TEST

551-5.3.1 In order to determine compressor capacity, bulky and expensive special equipment is required. Hence, it is impractical to attempt accurate capacity tests after compressors have been installed aboard ship. However, if the compressor is kept in good condition, its capacity should not appreciably change throughout its life.

551-5.3.2 A capacity check may be made by the pump up method. According to this method, the air delivered by the pressure rise is discharged into a closed tank of known capacity, the pressure rise in a given time is noted, and temperatures at the beginning and end of test are observed. From this data, the weight of air pumped into the tank may be computed and can be expressed as volume delivered by the compressor per unit of time.

551-5.3.3 It should be understood that the results obtained by this method are only approximate, due to the error in computing the volume of the tank and attached piping and to the difficulty of obtaining the true temperature within the tank. Within these limitations, the test has certain practical value. Hence, the actual delivery of the compressor in ft^3 /min of free air, again utilizing the same formula, is:

$$(PD)(VE) = V(P_2 - P_1)/P_A (T)$$

APPENDIX A.

REQUIREMENTS FOR ULTRASONIC INSPECTION OF COMPRESSED GAS FLASKS

551-A.1 SCOPE

551-A.1.1 These requirements apply to the ultrasonic examination of compressed gas flasks. An ultrasonic inspection is performed to detect wall thinning, axial cracks, and circumferential cracks in the main body of the flask. Hemispherical heads are ultrasonically inspected for wall thinning.

551-A.2 REFERENCE DOCUMENTS

551-A.2.1 Reference (a) forms a part of this procedure to the extent specified herein.

a. MIL-STD-271, **Requirements for Nondestructive Testing Methods**

551-A.3 PROCEDURE

551-A.3.1 Ultrasonic inspection procedures shall be prepared in accordance with this document. The procedures shall meet the requirements of MIL-STD-271 (except as modified herein) and be qualified in accordance with MIL-STD-271.

551-A.4 PERSONNEL

551-A.4.1 Inspection personnel shall be certified in accordance with MIL-STD-271 and be thoroughly familiar with the requirements of this document.

551-A.4.2 Inspection personnel performing Appendix B discontinuity sizing measurements shall be qualified and certified in accordance with Appendix B.

551-A.5 EQUIPMENT

551-A.5.1 Ultrasonic equipment shall meet the requirements of MIL-STD-271.

551-A.5.2 Ultrasonic reference calibration standards shall meet the requirements of MIL-STD-271. A block is required for thickness measurements, circumferential crack detection (3 percent ID and OD notch), and axial crack detection (3 percent ID and OD notch). The block shall be fabricated from a piece of a scrapped flask or an acoustically similar material as defined in MIL-STD-271. The calibration block shall have a surface finish and curvature similar to the flasks to be inspected (see 551–A.7.1 and 551–A.7.2 for exceptions for painted surfaces). An 18-inch diameter flask and a 20-inch diameter flask are considered to have similar curvatures. A separate calibration standard is not required for the three inches of scanning performed on each of the hemispherical heads (different curvature).

551-A.5.3 The ultrasonic transducer for thickness measurements may be either the single element or dual element design. The transducer for angle beam inspection shall have an active element size of 3/4″ x 1″ with a nominal frequency of 2.25 to 5 MHz. For shear wave inspection, the transducer shall be affixed to a suitable wedge designed to produce shear waves in the material at 45 ± 3 degrees.

551-A.5.4 Ultrasonic couplant shall be in accordance with MIL-STD-271. Oil or oil-based couplants shall not be used without approval of the shipyard code responsible for cleaning and painting the flasks. The couplant used for calibration shall be used for inspection. Couplant shall be removed upon completion of the test.

551-A.6 SURFACE PREPARATION

551-A.6.1 ULTRASONIC INSPECTION. The examination surface shall be free of loose or bubbled paint, grease, dirt, and any other foreign material that might interfere with scanning. Tightly adhering paint does not require removal. Average surface roughness shall be 250 RMS or better. Surface waviness shall not interfere with search unit contact.

551-A.7 ULTRASONIC CALIBRATION

551-A.7.1 The inspection system shall be calibrated prior to each scanning session or shift, at any equipment change (instrument, search unit, cable, etc.), and at the completion of the inspection. If the calibration check indicates that recalibration is required, all areas inspected since the last valid calibration shall be re-inspected.

551-A.7.2 For thickness measurements through paint, either a multiple echo technique shall be used or the thickness calibration standard shall be painted with a thickness of paint of a similar paint system equal to the average thickness of the paint on the flask under inspection, plus or minus 0.005 inch. A minimum of five paint thickness measurements shall be made at random locations on each flask to determine the average paint thickness.

551-A.7.3 For shear wave inspection through paint, an attenuation correction is required to compensate for the effect of the paint on the test sensitivity. A comparison shall be made between the part to be inspected and the specific reference standard to be used. The comparison shall be based on a two transducer pitch-catch shear wave signal obtained from similar geometrical areas on the reference standard and the flask. The transducers used for the attenuation check shall be the same type, frequency and angle as that which will be used for inspection. A minimum of three random locations shall be evaluated on the flask. Compensation for paint attenuation, measured to the nearest dB, shall be added to the instrument gain after the conventional calibration is performed on the unpainted calibration block. The most attenuative area measured on the flask shall be used to determine the correction value.

551-A.7.4 Calibration shall be performed in accordance with the ring forging shear wave calibration requirements in MIL-STD-271 (i.e., inspection is performed between the 1/2 skip and 1-1/2 skip).

551-A.8 ULTRASONIC SCANNING

551-A.8.1 Thickness measurements shall be made at the intersections of a 6 inch by 6 inch grid ± 1/2 inch tolerance on inspection points over the entire surface of the flask, including the heads. Any area of visible corrosion on the flask shall be also measured near the center of the area. Localized areas of wall thinning shall be continuously scanned to their extremities to ensure that the deepest area of thinning has been measured.

551-A.8.2 Shear wave inspections shall be performed over 60 percent of the entire flask body in both the axial and circumferential direction, including three inches into each hemispherical head (i.e., three inches toward the neck from the point where the flask body first curves to form the head). This 60 percent should include as much as is practical of the bottom third of the flask's cylindrical section with the remainder taken as a random sample. Scanning is only required in one axial direction and one circumferential direction. Continuous scanning with a minimum of 25 percent overlap shall be used.

551-A.9 ACCEPTANCE CRITERIA

551-A.9.1 ULTRASONIC THICKNESS INSPECTION. Flasks with a measured wall thickness below the required minimum wall thickness listed in Table 551-1-4 shall be rejected.

551-A.9.2 ULTRASONIC SHEAR WAVE INSPECTIONS. Discontinuities with a maximum amplitude that exceeds the amplitude of the 3 percent calibration reflector shall be sized in accordance with Appendix B. Results of the inspections shall be forwarded to NAVSEA for disposition. Discontinuities with a maximum amplitude that exceeds 50 percent of the amplitude of the calibration reflector and with a length over 3 inches shall be reported to NAVSEA for information.

551-A.10 RECORDING AND REPORTING

551-A.10.1 A separate flask inspection report prepared in accordance with MIL-STD-271 shall be completed for each flask inspected. Flasks shall be identified as defined by the shipyard design code. Reference lines or a grid shall be established to accurately record discontinuity position. The same reference lines shall be used for the thickness measurements, shear wave crack detection scans, and crack sizing inspections (if performed).

551-A.10.2 The following information shall be included in the report:

a. Hull number.
b. Flask identification, size and type.
c. Ultrasonic procedure(s) identification and revision number.
d. Inspector's name, level, and signature.
e. Date of each inspection.
f. Type of material inspected.
g. Equipment description and serial numbers (ultrasonic instruments).
h. Ultrasonic transducer manufacturer, frequency, size, angle, and serial number.
i. Ultrasonic couplant used.
j. Ultrasonic calibration standard serial numbers.
k. If ultrasonic inspection is performed through paint, describe the paint condition and the specific technique used to compensate for paint (thickness measurement and shear wave inspections).
l. Assign a unique number to each reportable discontinuity.
m. Report the specific location of each discontinuity on the flask. Reporting shall be such that the area can be relocated after the flask is painted. Unless otherwise specified by the shipyard design code, report all discon-

tinuities using the inboard, top point of the flask where the hemispherical head just begins to form as a standard reference point. Report all discontinuities in the body of the flask from this point in terms of (1) inches down the flask along the inboard surface of the flask and (2) inches around the circumference of the flask (measured in a counter-clockwise direction, as viewed from the top of the flask). For discontinuities in the head region or skirt attachment weld, use a sketch to report the locations. Mark the location of the standard reference point described above on the sketch.

n. Record the length of the discontinuity, and the method used to measure the length (e.g., ultrasonically measured using a 6 dB drop technique).

o. Record the orientation of the discontinuity (e.g., relative to the flask axis or weld direction).

p. Enter ultrasonic peak amplitude in dB, relative to reference level.

q. Enter the location of the discontinuity from the scanning surface (for ultrasonically detected discontinuities).

r. Enter the characterization of the discontinuity, as determined from Addendum A, Ultrasonic Discontinuity Characterization Requirements. Add notes and sketches to aid in characterizing the discontinuity (open to ID, open to OD , detected by inspection, etc.).

s. All ultrasonic thickness measurements including grid locations.

APPENDIX B.

ULTRASONIC DISCONTINUITY CHARACTERIZATION REQUIREMENTS

551-B.1 CONDITIONS REPORTED AS A RESULT OF ULTRASONIC THICKNESS EXAMINATION

551-B.1.1 Rescan the area with an ultrasonic instrument with an A-scan presentation and a similar transducer to that originally used. Verify that the same location on the flask has been identified. The maximum wall loss should be approximately the same as the initial report. Significant disparity (greater than ± 3 percent) between the two measurements should be resolved by the Level III.

551-B.1.2 By reviewing the A-scan presentation during scanning, determine if the discontinuity appears to be a lamination or inclusion in the wrought material or thinning or corrosion on the back side of the wall using the following evaluation criteria:

a. The entire area of a lamination or inclusion will measure to be at approximately the same depth in the wall. The thinning or corrosion will taper toward the extremities resulting in a ″walking″ of the signal on the A-scan.

b. The signal appearance in the middle of a lamination or inclusion will be sharp, similar to that which results from the back surface of an non-thinned plate. The signal appearance of a thinned or corroded area will be broader as a result of the sound reflecting back from the different depths of the rough surface.

c. Apply the MIL-STD-271 shear wave examination to the area, interrogating it from all directions. A lamination or inclusion will not show any signal at the inner wall surface while a thinned or corroded area will result in a ″walking″ signal from the inner wall all the way to the deepest reported area. Higher instrument gain settings shall be used, if necessary, such that the inner surface noise or ″roll″ away from the suspect area is visible.

d. For the evaluation of small localized areas-small being defined as area smaller than the transducer used for the wall thickness measurements-apply the 30-70-70 technique to the area, interrogating it from all directions. The 30-70-70 technique is described in Appendix C to this chapter. The presence of shear-to-shear (SS) signal, which includes the generation of an ID creeping wave, indicates that there is some vertical component of thinning or corrosion in the area. Absence of the SS signal indicates that the suspect condition is an embedded lamination or inclusion.

551-B.1.3 In addition to the reporting requirements in the body of this document, report the results and observations of the performance of each step of the evaluation criteria above (the 30-70-70 is not always performed). Add additional comments to explain the condition or suspected condition. Characterize the condition as either ″thinning or corrosion″ or ″lamination or inclusion.″ If conflicting information makes the characterization uncertain, report the condition as ″unknown.″

551-B.2 CONDITIONS REPORTED AS A RESULT OF MIL-STD-271, ULTRASONIC SHEAR WAVE EXAMINATION

551-B.2.1 Rescan the area with the shear wave scan and verify that the same location on the flask has been identified.

551-B.2.2 Determine if the discontinuity appears to be a crack or crack-like discontinuity open to the back surface, an embedded inclusion in the wrought material, or a thinning or corrosion condition on the back side of the wall using the following evaluation criteria:

a. Scan the area in accordance with the requirements in paragraph 551-B.1, Conditions Reported as a Result of Ultrasonic Thickness Examination.

b. Apply the MIL-STD-271 shear wave examination to the area, interrogating it from all directions. A fatigue crack will almost always be oriented with its axis aligned with the longitudinal axis of the flask. Fabrication cracks or crack-like planar discontinuities (a seam or lap in the material) will predominantly lie in the longitudinal direction, but could lie in any direction.

c. Apply the 30-70-70 technique to the area, interrogating it from all directions. The 30-70-70 technique is described in Appendix C to this chapter. The presence of the shear-to-shear (SS) signal, which includes the generation of an ID creeping wave, indicates that there is a crack or crack-like discontinuity open to the back surface or there is some vertical component of thinning or corrosion in the area. Absence of the SS signal indicates that the suspect condition is an embedded lamination or inclusion.

551-B.2.3 In addition to the reporting requirements in the body of this document, report the results and observations of the performance of each of the evaluation criterion above (including the results of the paragraph 551-B.1 evaluations). Add additional comments to explain the condition or suspected condition. Characterize the condition as either ″thinning or corrosion,″ ″lamination or inclusion,″ or ″crack or crack-like.″ If conflicting information makes the characterization uncertain, report the condition as ″unknown.″ All crack or crack-like conditions shall be sized in accordance with Appendix C.

APPENDIX C.

STANDARD PROCEDURE FOR ULTRASONIC THROUGH-WALL SIZING OF SURFACE-BREAKING DISCONTINUITIES IN COMPRESSED GAS FLASKS

551-C.1 SCOPE

551-C.1.1 This procedure provides requirements for the through-wall sizing (depth) of surface-breaking discontinuities in high pressure steel flasks using the ultrasonic (UT) method. This procedure should only be applied after an ultrasonic characterization evaluation such as that required by Appendix A has been applied and concluded that the discontinuity to be sized is believed to be a crack or crack-like discontinuity open to the inside or outside flask surface.

551-C.1.2 While this procedure is applicable to through-wall sizing of surface-breaking cracks in metals such as Intergranular Stress Corrosion Cracking and cracks which occur during fabrication, it was developed primarily for the sizing of suspected fatigue cracks. This procedure is not applicable for sizing volumetric flaws such as inclusions, porosity, corrosion, gouges or cracks that do not break the surface.

551-C.1.3 This procedure is applicable only to the sizing of single isolated cracks and may not be used for sizing multiple cracks or a single crack within multiple cracks.

551-C.1.4 The accuracy of the crack-sizing procedures described in this procedure are dependent upon operator training and ability to correctly interpret the ultrasonic signal responses. Sizing accuracy is typically 0.05 inch to 0.10 inch. However, each technique or variation of technique should be demonstrated to determine the accuracy for the given material thickness and flaw type.

551-C.1.5 This procedure describes techniques that are applicable on components in the thickness range of 0.25 to 2.5 inches.

551-C.2 REFERENCED DOCUMENTS

551-C.2.1 MILITARY STANDARDS. MIL-STD-271, Requirements for Nondestructive Testing Methods

551-C.2.2 ASTM STANDARDS

a. ASTM E 164,Ultrasonic Examination of Weldments
b. ASTM E 317, Evaluating Performance Characteristics of Ultrasonic Pulse-Echo Testing Systems Without the Use of Electronic Measurement Instruments
c. ASTM E 1316, Standard Terminology for Nondestructive Evaluation

551-C.3 TERMINOLOGY

551-C.3.1 The following terms supplement the standard terminology in ASTM E 1316.

551-C.3.1.1 Creeping Wave: A creeping wave is a longitudinal wave traveling nearly parallel and along the metal surface. It can be generated on the probe-side surface of a material through the use of a high angle (usually 70° or higher) longitudinal wave designed wedge. A creeping wave can also be generated along the surface opposite the probe through mode conversion of approximately 33° shear waves impinging on the back surface. Specialized transducers and wedges specifically designed to generate creeping waves for sizing applications are usually used.

551-C.4 ABBREVIATIONS

a. L-wave - longitudinal wave

b. S-wave - shear wave

c. LL - a reflected L-wave

d. LS - an L-wave produced by mode conversion from an S-wave

e. SS - a reflected S-wave

f. RATT - Relative Arrival Time Technique

g. AATT - Absolute Arrival Time Technique

h. SNR - Signal to Noise Ratio

i. SDH - Side-Drilled Hole

551-C.5 PERSONNEL QUALIFICATION AND CERTIFICATION

551-C.5.1 Inspections performed in accordance with this procedure shall be performed by qualified personnel who are certified as a Level II or III in accordance with MIL-STD-271. All personnel who perform sizing examination should be trained in the specific techniques in this procedure and demonstrate sizing proficiency on samples suitable to the activities of Level III. It is highly recommended that examination personnel acquire training on samples with real cracks and that their training not be limited to only examining notches. This recommendation is made because the crack tip signals may be difficult to detect, as they can be much smaller than the notch tip signals. A practical performance examination on samples with cracks shall be administered as part of the qualification.

551-C.6 MATERIAL AND EQUIPMENT

551-C.6.1 COUPLANT. The couplant requirements should be in accordance with MIL-STD-271.

551-C.6.2 INSTRUMENT. A pulse-echo or transmit-receive ultrasonic instrument with an A-scan presentation shall be used, depending upon the actual type of search unit used. The instrument shall be capable of generating and receiving signals in the frequency range of the search units being used, and shall be qualified in accordance with MIL-STD-271.

551-C.6.2.1 A radio frequency (RF) display mode is desirable, but is not required. The RF display may provide signal characteristics which improve the ability to identify the tip diffracted signals. For example, tip diffracted signals will usually have a phase opposite that of a crack-base corner reflected signal. Tip-diffracted signals tend to have low signal-to-noise ratios.

551-C.6.3 SEARCH UNIT. Search units may contain either single or dual transducer elements, depending upon the specific sizing technique being applied.

551-C.6.3.1 In general, search units with a nominal center frequency range of 1.5 MHz to 5.0 MHz should be used. Higher frequencies may be used to improve resolution and sensitivity on materials with low attenuation.

551-C.6.3.2 Search units may be self-contained or used in conjunction with wedges. Search units may produce shear waves, longitudinal waves, creeping waves or a combination of these wave modes.

551-C.6.4 WEDGES. Detachable wedges that produce shear or longitudinal waves at the desired refracted angles may be used. Detachable wedges may also be used to produce creeping waves.

551-C.6.4.1 Contoured contact wedges may be used to match the specimen configuration and to aid ultrasonic coupling, although they will limit the ability to swivel the search unit.

551-C.6.4.2 If detachable wedges are used, calibration should be done with the same contact wedge used during the examination.

551-C.6.5 BASIC CALIBRATION BLOCKS AND REFERENCE STANDARDS. The mechanics of ultrasonic crack sizing requires the use of special sizing calibration and reference blocks.

551-C.6.5.1 Sizing calibration blocks shall have a thickness within 5 percent of the nominal thickness of the component being examined and contain the notches and holes described below.

551-C.6.5.1.1 The block shall have at least five notches with depths of 10, 20, 40, 60, and 80 percent of the thickness (all ±0.010 inch) (see Figure 551-C.1). Additional or other notch depths that cover the full thickness range of the component may be used. The spacing between adjacent notches should be sufficient to avoid confusing indications from multiple notches.

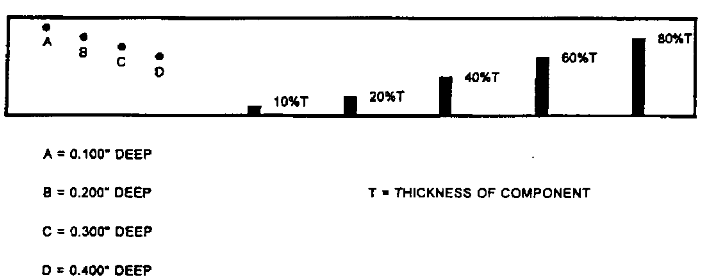


Figure 551-C-1 Typical Calibration Block for Crack Sizing

551-C.6.5.1.2 Side-drilled holes at depth intervals of 0.100 inch for the range of calibration depth (usually 0.500 inch) shall be included for creeping waves. The diameter of the side-drilled holes should be as small as practical (i.e., 1/16 inch or smaller).

551-C.6.5.1.3 The block shall be fabricated from a piece of a scrapped flask or an acoustically similar material as defined in MIL-STD-271. The calibration block shall have a surface finish and curvature similar to the flasks to be inspected. An 18-inch diameter flask and a 20-inch diameter flask are considered to have similar curvatures. A separate calibration standard is not required for scanning performed on the first three inches of each of the hemispherical heads (different curvature). Notches and holes must be provided for scanning in both the flask longitudinal and circumferential directions. The configuration of the holes and notches in Figure 551-C.1 is intended only as an example. Multiple blocks may be used.

551-C.7 PROCEDURE QUALIFICATION

551-C.7.1 Equipment and procedures used to implement the requirements of this standard shall be qualified on samples that contain either service-induced or artificially-induced cracks.

551-C.8 PREREQUISITES

551-C.8.1 Areas to be scanned will be determined by previous ultrasonic detection examinations. Select intervals along the length of the crack to be sized to obtain a profile of the crack and to aid in identifying the deepest point.

551-C.8.2 When required, surface preparation may be accomplished by manual or mechanical means such as wire brushing or sanding.

551-C.9 DESCRIPTION OF CRACK-SIZING TECHNIQUES

551-C.9.1 GENERAL. This procedure recommends four basic techniques for sizing cracks: tip diffraction, creeping wave, 30-70-70, and Bi-Modal. These techniques are based primarily on crack-tip diffraction and can be divided into single-wave mode and multiple-wave mode techniques. As the names imply, the single-wave mode techniques use only a single mode of ultrasonic waves, (i.e., shear, longitudinal or creeping) while the multiple-wave mode techniques use two or more modes of ultrasonic waves (i.e., both shear and longitudinal). In either case, the arrival time of the crack-tip signal relative to a certain reference is used to determine the crack depth.

551-C.9.2 SINGLE-WAVE MODE TECHNIQUES. In the single-wave mode techniques, the ultrasonic search unit transmits a single-wave mode, longitudinal or shear waves, toward the crack. The wave is directed so as to obtain a signal from the crack tip. The arrival time of this crack-tip signal relative to a certain reference is used to measure the crack depth or remaining ligament of sound material. Other than longitudinal and shear wave modes that measure the crack depth, the creeping waves are used as a means of identifying deep cracks. Creeping waves propagate close to the examination surface and detect cracks that are approximately 0.10 to 0.50 inches of the examination surface. The depth detection range of creeping waves should be determined on the calibration block with the side drilled holes.

551-C.9.3 RELATIVE ARRIVAL TIME TECHNIQUE (RATT)

551-C.9.3.1 Technique

a. The RATT technique measures the time difference between the crack-tip and the crack-base signals. As shown in Figure 551-C.2, the time difference between these two signals increases with increasing crack depth. This measurement can therefore be used to calculate the crack depth. The deeper the crack, the greater the screen distance DS.

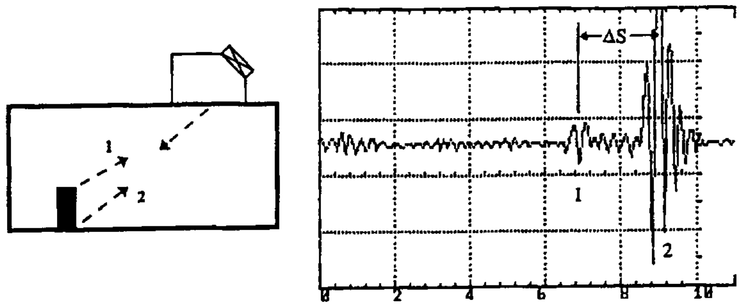


Figure 551-C-2 Application of the RATT Diffraction Technique

b. A refracted angle in the range of 40 to 60 degrees is recommended with this technique. Shear-wave angles lower than 40 degrees are not used because of weak crack-tip signals and shear-wave angles higher than 60 degrees are not used because of reduced resolution between the crack base and tip signal.

c. In general, the RATT technique is easier to apply for shallow cracks that are 0.10 to 0.30 inch deep where both the crack-tip and crack-base signals are observed simultaneously (Figure 551-C.2). For deeper cracks, the crack-tip and the crack-base signals may not be observed simultaneously. Although not generally used for deeper cracks, a RATT calibration and measurement can still be made by marking the peak location of the crack-tip signal (1) and the peak location of the crack-base signal (2) on the time-base of the instrument screen and making the measurement. The peak point of both signals will not occur at the same search unit location. When moving the search unit toward the crack, the crack-base signal (2) will peak first followed by the crack-tip signal (1).

551-C.9.3.2 Calibration

a. The RATT technique is calibrated on the 10 percent notch.

b. Adjust the range and delay controls to peak the notch signal (2) at approximately the 8th division. Obtain an acceptable separation between the notch-tip and the notch-base signal.

c. A suggested calibration is to adjust the range such that one major screen division on the time-base represents 10 percent notch depth. Calibration of the technique should be checked on the 20 percent notch.

551-C.9.4 ABSOLUTE ARRIVAL TIME TECHNIQUE (AATT)

551-C.9.4.1 Technique

a. The AATT technique is generally used to size deep cracks where both the crack-base and crack-tip signals cannot be observed simultaneously. As shown in Figure 551-C.3, the arrival time of the crack-tip signal is measured and related to the crack depth. The deeper the crack, the smaller the screen distance DS.

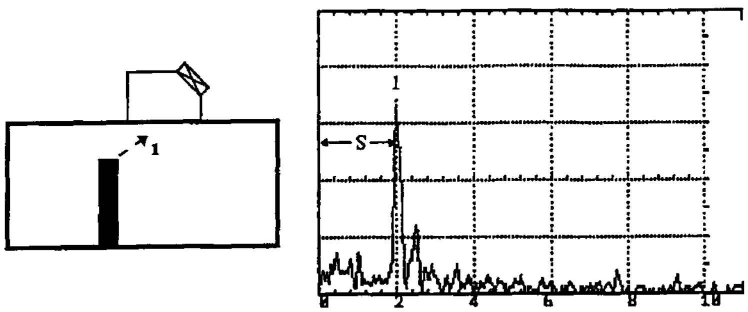


Figure 551-C-3 Application of the AATT Tip Diffraction Technique

b. This technique can be applied using either shear or longitudinal waves, although shear waves are typically used whenever possible. The refracted angle can be any value between 40 to 70 degrees. Selection of the beam angle can sometimes be dictated by accessibility for the search unit.

551-C.9.4.2 Calibration

a. The AATT calibration is performed such that the extreme left of the screen represents a through-wall crack and the 4th major division represents an 80 percent deep crack.

b. The calibration is performed by obtaining the peaked crack-tip signal from the 20, 40, 60, and 80 percent deep notches. The instrument is adjusted so that the peaked tip signals from these three notches fall at the 4th, 3rd, 2nd and 1st screen divisions, respectively.

551-C.9.5 CREEPING WAVES AND HIGH-ANGLE LONGITUDINAL WAVES

551-C.9.5.1 Technique

a. Creeping waves are high-angle longitudinal waves that travel close to the examination surface. They are produced with wedges that generate 60 to 90 degree refracted L-Waves.

b. Creeping waves do not measure crack depth directly but measure the remaining ligament of material above the crack tip. Application of the creeping-wave technique is shown in Figure 551-C.4.

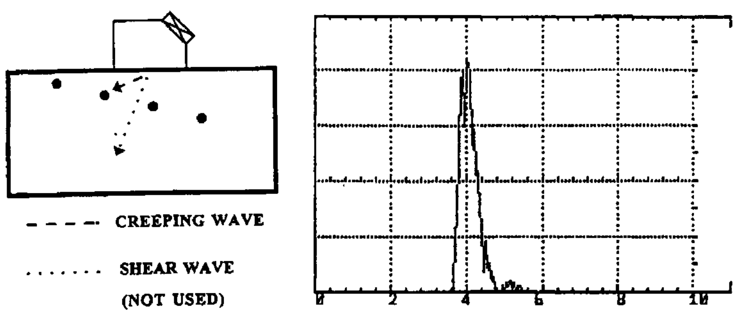


Figure 551-C-4 Application of the Creeping-Wave Technique

c. The technique can sometimes be confusing as the creeping-wave search unit also produces 30 to 35 degree shear waves that can reflect from the crack base. This signal should be recognized and accounted for and not confused with the creeping wave.

551-C.9.5.2 Calibration

a. Calibration of creeping waves is performed using side-drilled holes close to the examination surface as shown in the sizing calibration block (Figure 551-C.1). The creeping-wave search unit should be able to detect the side-drilled holes in the calibration block.

b. The delay and range should be adjusted so that reflection from the 0.100 inch and 0.200 inch deep side-drilled holes occur at the 1st and 2nd major division, respectively.

551-C.9.6 Multiple-Wave-Mode Techniques. The multiple-wave-mode techniques use the information produced by both the shear and the longitudinal waves to estimate crack depth. There are two types of multiple-wave-mode techniques. The first is called the 30-70-70 or ID creeping wave technique and the second is called the Bi-Modal technique. The 30-70-70 technique does not measure the crack depth but qualitatively determines whether the crack is deeper than approximately 15 percent of the component thickness.

551-C.9.7 30-70-70

551-C.9.7.1 Technique

a. The 30-70-70 technique uses a search unit that produces a shear wave at a nominal angle of 30 degrees and a longitudinal wave at a nominal angle of 70 degrees as shown in Figure 551-C.5 (hence the name 30-70-70).

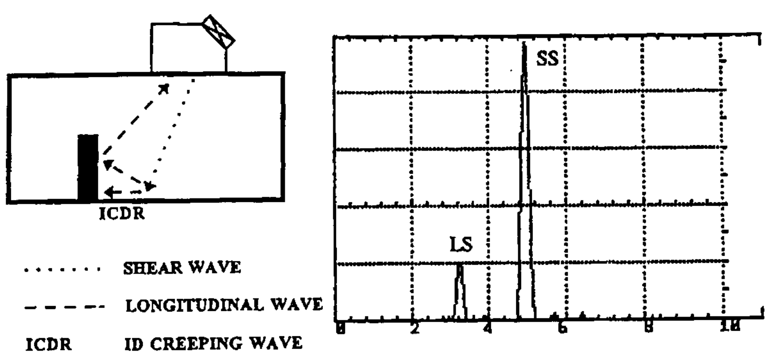


Figure 551-C-5 Application of the 30-70-70 Technique

b. Depending on the crack depth, this search unit can produce up to three signals from the crack. A shear-to-shear (SS) signal, which includes the generation of a ID creeping wave which is reflected from the crack-base, is always produced. This SS signal is produced by incident shear waves that mode convert to critically refracted L-waves or creeping waves at the far surface. These mode-converted waves produced at the far surface reflect off the crack and re-generate shear waves that are received by the search unit. As the transducer is moved closer to the crack, the creeping wave travel path reduces to zero where the SS signal becomes a direct reflection of the 30 degree shear wave. When the crack depth exceeds approximately 15 percent of the thickness, an LS signal is produced.

NOTE

The 15 percent value is based on a component thickness of approximately 1 inch. This value will change with component thickness and its value on other thicknesses can be measured on a block with a thickness the same as that to be inspected with a range of notch depths.

c. This LS signal arrives earlier than the SS signal. The LS signal is the 30 degree shear-wave signal that mode converts at the back surface, reflects off the crack face, and returns as an L-wave. For extremely deep cracks that are within 0.5 inch of the examination surface, a longitudinal- to-longitudinal (LL) signal is produced. This sometimes very weak signal arrives earlier than both the LS and SS signals. The LL signal can be either a direct reflection from the crack face or a crack tip diffracted signal.

d. As is evident from the above discussion, the multi-pulse response produced with the 30-70-70 technique depends upon the depth of the crack. Therefore, this technique is applied to categorize the crack depth into one of the following ranges: less than 15 percent of component thickness (only SS signal), greater than 15 percent of component thickness (LS and SS signals), or very deep (LL signal). Although not detailed here, the technique can be applied where the LL signal is calibrated for measuring the crack depth.

551-C.9.7.2 Calibration

a. The calibration of the 30-70-70 technique is performed on the 20, 40, 60, and 80 percent notches.

b. The range and delay controls are adjusted so that the peaked SS wave from any of the notches (since this is a signal from the base of the notch) is obtained at the 5th division.

c. Next obtain the signal response from the 60 percent notch. This notch should produce two strong signals (LS and SS).

d. Adjust the delay and range controls to obtain the peaked LS signal at the 4th division and the peaked SS signal at the 5th division. The location of these two signals on the screen should be the same for all of the deeper notches.

551-C.9.8 BI-MODAL SIZING

551-C.9.8.1 Technique

a. This technique is an enhancement of the RATT approach whereby relative measurements can be directly made on shallow or deep cracks. As discussed earlier, deeper cracks fail to produce both the crack-tip and crack-base signal simultaneously using the single-wave mode technique. This is because a search unit has a limited beam spread that fails to insanity both the tip and the base of a deep crack. The Bi-Modal technique primarily addresses this limitation of the single mode technique by increasing the beam spread using two tandem-mounted transducer elements (i.e., one in front of the other) so that both absolute and relative measurements can be made simultaneously (Figure 551-C.6). The transducer elements are placed on a specially designed wedge so as to illuminate both the crack tip and the crack base. The wedge angles selected are dependent on the component thickness, although standard Bi-Modal probes are usually only offered by the specialty probe manufacturers in one or a few standard angles.

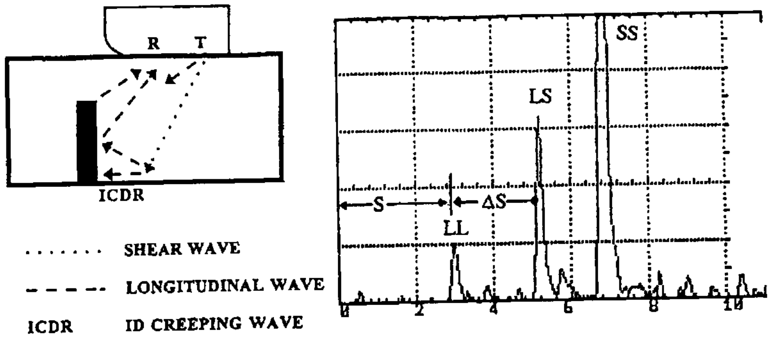


Figure 551-C-6 Application of the Bi-Modal Technique

b. The search unit operates in the transmit-receive mode and results in three signals: SS from the crack-base, LS from the crack face, and LL from the crack tip, as shown in Figure 551-C.6. For some cracks, a fourth signal, LL from the crack base, may be observed.

c. The time difference between the LS and SS signals does not change with change in crack size, but it is affected by a change in component thickness or crack orientation.

d. The time separation of the LL wave from both LS and SS increases with increase in crack depth. This increase in separation, primarily LL to LS, is used to measure crack depth.

551-C.9.8.2 Calibration

a. The range and delay controls are adjusted so that the LL signal peaks from the 1st to the 4th major division as the notch depth decreases from 80 percent to 20 percent, respectively. This is performed by placing the peaked LL signal from the 80, 60, 40, and 20 percent notches at the 1st, 2nd, 3rd, and 4th major divisions (alternatively, other screen setting can be used).

b. Next, measure the separation of the LL signal from the LS signal with increase in notch depth. This separation of signals vs. crack depth can be plotted and used as calibration curve. Additionally, the direct measurement of the LL pulse-arrival time can be used to obtain another measurement of crack depth.

551-C.10 RECOMMENDED PRACTICE

551-C.10.1 The nature of cracking dictates the use of multiple techniques to accurately size cracks of various through-wall dimensions. It is highly recommended that verification of the through-wall dimension of a crack be made using more than one technique whenever possible.

551-C.10.2 It is recommended that the 30-70-70 technique be the first technique applied to a suspected crack. This technique can be used to initially categorize the crack as shallow (less than 15 percent of component thickness), greater than 15 percent of component thickness, or very deep. This categorization gives the operator a general idea of the crack depth relative to the component thickness and helps in selecting additional crack-sizing techniques.

551-C.10.2.1 Deep cracks that are 75 percent of component thickness or greater are identified by using 70 degree shear, 70 degree L-waves or creeping waves.

NOTE

The 75 percent value is generally accepted for a 1-inch thick component. Cracks shallower than 75 percent will be detectable on thinner components while cracks deeper than 75 percent will be detectable on thicker components.

A deep crack will reflect these high angle waves. It is recommended that all these wave modes be applied from both sides of the crack, if possible.

551-C.10.2.2 Shallow cracks that are 15 percent (again this percent value depends on the component thickness) of component thickness or less in depth are identified by using the 30-70-70 search unit. These cracks will fail to produce the LS wave as discussed in paragraph 551-C.9.3.1. Only a single SS signal is reflected from a small crack. Application of the 30-70-70 technique may be difficult in certain welds as signals reflected from the weld counterbore can confuse the expected pattern of signals from the crack.

551-C.10.3 The major through-wall dimensioning techniques utilized in this standard should be the following:

551-C.10.3.1 The AATT approach using the 70 degree refracted shear or longitudinal wave technique should be used for cracks that penetrate to near the examination surface.

551-C.10.3.2 The half-vee RATT and half-vee AATT should be used for cracks that have through-wall dimensions that range between 0.100 inches from the far side surface to 0.200 inches from the examination surface.

551-C.10.3.3 The full-vee path mode should be used with AATT or RATT on cracks that initiate from the examination surface (see Figure 551-C-7). Multiple-wave mode techniques cannot be used in the full-vee path mode.

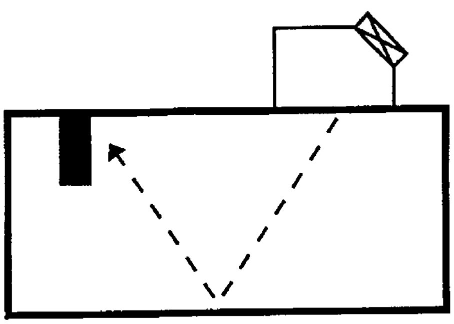


Figure 551-C-7 Application of RATT/AATT in a Full Vee Path

551-C.10.3.4 The Bi-Modal technique should be used for cracks that range from 20 percent to 80 percent through-wall.

551-C.10.4 Each technique has certain advantages, disadvantages and applications. No single technique is adequate to size all flaws in all material thicknesses. It is important to understand the advantages and limitations of each technique so that the best combination of techniques may be used.

551-C.10.5 These crack sizing techniques can give erroneous results if signals are misinterpreted. Some of the possible causes of misinterpretation and errors in crack sizing are as follows:

a. Signals reflected from inclusions near the crack can be misinterpreted as crack-tip signals; hence, the crack is oversized.

b. Signals reflected from geometrical reflectors can be misinterpreted as crack-base signals or crack face signals.

c. Signals reflected from multiple or oriented cracks can confuse the interpretation. In general, these techniques should not be used on multiple cracks.

d. Noise from artifacts on surface can produce surface wave or creeping wave signals when using high angle waves.

e. Velocity and thickness differences between the sizing calibration block and the component material can cause infusing signals.

551-C.11 SCANNING

551-C.11.1 The designated area should be scanned along the crack length for each crack depth zone. The greatest through-wall dimension observed along the length of the crack should be chosen for depth determination.

551-C.11.2 The presence of the anticipated response should confirm the presence of the crack in the depth zone being investigated. The absence of the anticipated response may verify the absence of the crack in the depth zone being investigated, but should not be assumed until a conclusive measurement of the crack has been obtained.

551-C.12 RECORDS

551-C.12.1 The greatest through-wall dimension for each individual crack obtained during the sizing examination should be recorded.

551-C.12.2 All examination results shall be documented and contain, as a minimum, the following:

a. Hull number.

b. Flask identification, size and type.

c. Ultrasonic procedure(s) identification and revision number.

d. Inspector’s name, level, and signature.

e. Date of each inspection.

f. Type of material inspected.

g. Ultrasonic equipment description and serial numbers.

h. Ultrasonic transducer manufacturer, wave mode, frequency, size, angle, and serial number.

i. Ultrasonic couplant used.

j. Ultrasonic calibration standard serial numbers.

k. Specific location of each discontinuity sized on the flask. Reporting shall be such that the area can be relocated after the flask is painted. Unless otherwise specified by the shipyard design code, report all discontinuities using the inboard, top point of the flask where the hemispherical head just begins to form as a standard reference point. Report all discontinuities in the body of the flask from this point in terms of (1) inches down the flask along the inboard surface of the flask and (2) inches around the circumference of the flask (measured in a counter-clockwise direction, as viewed from the top of the flask). For discontinuities in the head region or skirt attachment weld, use a sketch to report the locations. Mark the location of the standard reference point described above on the sketch.

l. Length of the discontinuity, and the method used to measure the length (e.g., ultrasonically measured using a 6 dB drop technique).

m. Orientation of the discontinuity (e.g., relative to the flask axis or weld direction).

n. Location of the extremities of the discontinuity from the scanning surface.

o. Additional notes and sketches to aid in characterizing the discontinuity (open to ID, open to OD, etc.).

REAR SECTION

NOTE

TECHNICAL MANUAL DEFICIENCY/EVALUATION EVALUATION REPORT (TMDER) Forms can be found at the bottom of the CD list of books. Click on the TMDER form to display the form.